

Frontispiece.



J. Devoto Invi.

Labuntur altis interim ripis aquae

Fontesque lymphis obstrepunt manantibus.

Toms sculp.

Hor.

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A N
INTRODUCTION
TO A GENERAL
SYSTEM
OF
Hydrostaticks and Hydraulicks,
PHILOSOPHICAL and PRACTICAL.

WHEREIN

The most reasonable and advantageous METHODS of raising and conducting Water, for the watering Noblemens and Gentlemens Seats, Buildings, Gardens, &c. are carefully (and in a Manner not yet publish'd in any Language) laid down.

CONTAINING IN GENERAL

A Physico-mechanical Enquiry into the Original and Rise of SPRINGS, and of all the Hypotheses relating thereto; as also the Principles of Water-works, and the Draughts and Descriptions of some of the best Engines for raising and distributing WATER, for the Supply of Country Seats, Cities, Towns corporate, &c.

Deduc'd from the Theory of *Archimedes, Gallileo, Torricelli, Boyle, Wallis, Plot, Hook, Marriotte, Desaguliers, Derham, Hawksbee*, and others.

Reduc'd to Practice by *Vitruvius, Bockler, de Caus*, and other Architects amongst the ancient *Romans, Italians, French, Flemmings, and Dutch*, and much improv'd by later Practice and Experience.

Illustrated and Explain'd by Sixty Copper Cuts, done by the best Hands, of the Principles which tend to the Explanation of the whole, and of rural Grotesque, and cheap Designs for Reservoirs, Cataracts and Cascades of WATER, Canals, Basins, Fountains, &c. Collected from the best of the *Italian and French* Designs (together with some new ones of the Author's own Invention) few of which have ever appear'd in Books of Hydrostaticks, &c.

In Two VOLUMES.

By STEPHEN SWITZER.

Sunt quippe (Hydrostaticæ) artis theoremata & problemata maximam partem genuina & pulchella soboles rationis circa argumenta attente pensitata rite se exercentis. — Etenim complura sunt, non ex familiaribus modis sua, & abstrusioribus naturæ Phenominis quæ nunquam capiuntur penitus neque Explicabuntur dilucide ab iis qui hospites sunt in Hydrostaticis; a quorum Principiis pendent, &c.

Boyle's Paradox. Hydrostat. Præfat.

L O N D O N :

Printed for T. ASTLEY, at the *Rose*, S. AUSTEN, at the *Angel* in *St. Paul's Church-Yard*; and L. GILLIVER, at *Homer's Head* against *St. Dunstan's Church, Fleetstreet.* M.DCC.XXIX.





TO THE
RIGHT HONOURABLE
ALGERNOON, Earl of Hertford,

*Baron Piercy, Beauchamp, &c. Lord Lieutenant
and Custos Rotulorum of the County of Sus-
sex, Custos Rotulorum of the County of Wilts,
Brigadier General of his Majesty's Forces, and
Captain of the Second Troop of Horse-Guards.*

MY LORD,



WITH an Address proportionate to the Honour and Dignity of those two illustrious Families, from which your Lordship has deduced your high Birth, I present this Volume of *Hydrostaticks* and *Hydraulicks* to your Patronage and Protection, depending upon two of the most valuable Epithets in humane Nature, *Your Affection to Arts and Sciences, and Benevolence to Mankind*: From both of which I am taught to hope you will encourage whatever tends to the Improvement of Mathematical and Philosophical Knowledge, and excuse

DEDICATION.

the Presumption of one, who places your Lordship's Favour and Friendship among the greatest Felicities of his Life.

IF the low Estate, and Unworthiness of the Author, should be any Objection to the Success of this Undertaking, the Usefulness of the Subject will (it is humbly hoped) sufficiently atone for it, especially if handled in a Manner suitable to the Nobleness of it. The History of Fluids being coeval with the World, and the most early Dawnings of Time it self; and upon the Cessation of which, Nature, with all her numerous Offspring, must necessarily recede and shrink back into its primary State (if I may so call it) of Non-entity and Annihilation, the Fluctuation of Fluids, the Elasticity, Clashing, and Recession of aerial and corpuscular Atoms, and minute Particles of Matter, consisting, as it does, of one of the greatest of her Laws, Motion (opposite to Stagnation and Rest) being the Machine by which she works all her Effects.

AND as the Theory of Fluids contains in it the greatest Scope of *Physico-Mechanical* and Philosophical Reasoning of any in Nature, and so of great Use to the moral and inquisitive Reader; so also the Practice of it, in raising and conducting Water, is no less useful to the industrious and busy Artisan and Mechanick, in the Beautifying and Embellishment of a Country Seat, Water being, if I may be indulged the Liberty of such an Expression, *the very Life and Soul of a Garden*; the wafting of Trees, the warbling of Birds, the *magnifique Boom*, being submissive Beauties, when put into Competition with the murmuring of Streams, and Cadence of Water.

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DEDICATION.

IT will not be to my Purpose, my Lord, nor shall I presume to enter into the Discussion of a Point long held in Debate, between the Advocates *pro* and *con*, which of the Water-works were the most noble, those of *Italy*, or those of *France*, leaving that to the Decision of your Lordship, and those ingenious Noblemen and Gentlemen of the *British* Nation, who are so impartial Judges of whatever is Natural, Noble and Polite; but thus far it appears by the Prints brought from thence, as well as from the Opinion of one of the greatest Genius's of this Age, *That the Water-works of Italy are generally more natural, than those of France, or contriv'd more agreeable to it; and that if the French do surpass them at present in their Gardens and Water-works, it is rather owing to the Greatness of their Riches, than the Excellence of their Taste.*

I know, my Lord, how disagreeable it will be to your Lordship, for me to expatiate on your Lordship's Character, either in publick or private Life, or at a History of those Noble Families from which you are descended (how just soever my Theme is); and I am the more unwilling to attempt it, lest the Description should fall short of the Subject, and the Picture suffer by the imperfect Shadows of so unmasterly a Hand; but as the most humble Cottager can't but look with cheerfulness on the cherishing Influences of a benign Sun; so, my Lord, I cannot without great Violence to my self, finish this Epistle, without those humble and sincere Offerings of Gratitude and Thanks for a Friendship, which is much more owing to your Lordship's kind Disposition, than to my Merit. Others look only upon those whom Fortune, or the Favour of the Great, rise
up

DEDICATION.

up to the Pinacles of Honour or Preferment; but your Lordship's good Nature overlooks that, and is the Cause that you extend your Notice to one in the lowest State of Life, and who can make no other Return, than that of Gratitude and Respect.

IF a sincere Friendship and good Nature, a benevolent and candid Deportment to all about you, be the true Characteristicks of a Gentleman of Humanity and Honour, well may I apply what the Historian says of one of the most beloved Patrons of Antiquity; *What Citizen? which of your Neighbours or Servants have you made uneasy? Which of your Friends or Family is it that you have anywise injur'd or disoblig'd?* Well would it be for Families and Estates in particular, as well as for the Peace of Society and the World in general, were those Patterns of frugal, social, and conjugal Virtues, of which your Lordship is so conspicuous an Example, more prevalent and extensive.

THAT these Gifts, the greatest and happiest which Omnipotence can confer on sublunary Beings, may be transmitted to your Posterity; and that the Illustrious Family of which your Lordship is so benevolent an Ornament, may be continued down in a direct Series, to the latest date of Time, is the sincere Wish of,

My LORD,

Your Lordship's Most Obedient

Humble Servant,

STEPHEN SWITZER.



THE PREFACE.

EVEN as *Paradise* itself, tho' of Divine Appointment, must have been deem'd an im-model'd and imperfect Plan, had it not been water'd by the same all-powerful Hand which first made it; so never can our Gardens and Fields (the nearest Epitomy and Resemblance of that happy and blessed Place to be met with here below) be said to be any way perfect or capable of subsisting without it.

THE entire want of Water that is in some, and the ill Use, or little Management of it, which is to be found in other Places, are, I humbly hope, sufficient to excuse me from making any Apology for my presuming to attempt at the undertaking of a System, the Steps
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of which so few have trod before me, and which I have with much Care and Pains drawn together, for the Improvement of these and future Times.

It were indeed to be wished, that some more able Hand, and who had more leisure than I have, would have undertaken so useful a Work as this is, which has not (at least that I know of) been drawn together into a System in any one Language whatsoever, but lies scattered up and down in Fragments and broken Pieces of Literature; on which Account I have adventured to throw in my Mite into this almost inexhaustible Treasury; which will, 'tis humbly hop'd, at least, have this good Effect, as to excite some more knowing Pen to perfect what I have thus willingly begun

It is not at all to be doubted, but this, as well as many other Works, which are produc'd for the Publick Good, will meet with its Disfavourers, as well as those who, out of a Value for the Improvements and Good of their Country, are willing to encourage all the Essays that are tending that Way, let them come from what Hand they will: To such therefore I have little to say; but proceed, after this short Introduction, to what is more generally intended in this Work, *viz. The properest Methods of raising and distributing Water for the Use of Country Seats, Towns Corporate, &c.*

It must be own'd, that the vast Expence which attends the raising up and conveying Water for the Embellishment and Watering of Noblemens and Gentlemens Seats, is one great Reason, that such Works are not oftener undertook and perfected than they are, the
Expence

The P R E F A C E.

iii

Expencc of piping of Drains, &c. being sometimes with Reason, (tho' at others with no Reason at all) an Intimidation to their Owners from conducting the Water thereto; not being able of themselves, nor having the Convenience of any about them to calculate the real Expencc that attends it: And this has been another Reason which has induc'd me to the following Essay, wherein I have, with as great Plainness as possible, set down the several Methods by which Water may be conveyed, because I have observed, that this being often left to those, (whose Business being rather to consult their own, than the Interest of those who employ them) have gone on in their own Way, tho' there are Ways much nearer, which has at last grown to an Expencc so great, as to deter the Owner from perfecting what he had thus injudiciously, and perhaps without any Consideration at all, begun.

N O R have I confin'd my self to what is purely practical, (how useful soever that be) but have introduced what I had to say, with all or most of those useful Propositions and Theorems that Writers in these Sciences have laid down, that so I might, as it were with a Clue of Thread, lead my Reader thro' the delightful Avenues and Approaches, till he is brought to the more satisfactory Pleasures which attend the solid Practice of them.

T H E first Thing I have attempted at, is an historical Account of the chief Works of this Kind, that were and are remarkable in ancient and modern Times, and the Rises and Honour they have contributed to the respective Places where they have been used, which has necessarily taken in a great many Observations of

considerable Use in the following Treatise; Observations so just in themselves, and of such great Consideration in Life, that whoever reads the Histories of those Times, will find, that the watering of a Town, and the preserving and conducting a Rivulet or a Spring (especially in military Affairs) was of as great Importance as the Conquest of an Enemy; and that without this Care, whole Armies have perish'd: *Cæsar* no Doubt was as remarkable for his Skill in Hydrostaticks, or rather Hydrophanticks, as he was in any other Effort he made for the Defence of his belov'd *Alexandria*, when he was so closely besieged in it; His whole Life, and some of the greatest and most politick of all his Actions also (as may be seen in the *Roman History*) being one continued Chain of Care, how he should procure Water for his Friends, and divert it from his Enemies, by which he often relieved his own, and starved the Armies of his Antagonists: And *Alexander*, how great soever he was in other Respects, was as remarkably negligent and supine in this, in suffering his Army to perish for Want of it.

Rome, even in its civil Capacity, was (as the Course of this Account will demonstrate) an eminent Instance of the Uses it was of to that Metropolis, in the stupendous Aqueducts with which it was on all Occasions supplied, such as caused *Fabretti*, a celebrated Author of Antiquity, to write a Treatise on Purpose concerning them; by which, as well as from *Pliny* and other Writers, we are assured they were accounted one of the Wonders of the World: Nor are *France*, *Italy*, as well as many other European Countries, much behind them

The PREFACE.

v

them, all which will be more amply considered in its proper Place.

THAT I might proceed the more methodically, the next Thing I have done, is the summing up all the different Hypotheses which have been laid down, relating to the Original and Rise of Springs, which I place as the Ground-work of this Undertaking; since that, as well as other Parts of Philosophy, whose Causes lie conceal'd, have long entertain'd the World with different Reasonings: All which I have endeavour'd as much as possible to reconcile, and to give every Opinion, which has any tolerable Appearance of Truth in it, its due Weight and Emphasis, not taking upon me absolutely to determine an Hypothesis, in which so many learned Men in all Ages have differed.

THE Original and Rise of Springs being thus cautiously, but I hope clearly handled, I have in the next Place treated in as short but yet plain a Manner as I could, of the good and bad Properties of Water, the Manner of discovering and searching for Springs, the taking of true Levels, in order to the conducting them home, where they are to be used in Aqueducts or Pipes of Conduet, according to the Practice of the most experienc'd in this Way; and this Book has necessarily taken in the cheapest and best Methods of Pipes, the making of Aqueducts, Reservoirs and Basons; because it is from the Want of this Knowledge that I suspect many great Designs of Water are laid aside, as not practicable or consistent with the Pockets of many Persons who have Occasion of it, in which I have more particularly explain'd the new invented, at least the so much new improv'd Earth Pipes,

Pipes, for which the ingenious Mr. *Edwards* of *Monmouth* has a Patent; and which, as we are inform'd, by the Reverend Dr. *Desaguliers*, in the *Evening Post* of *August 1st* this present Year 1727, did bear all the Compressure of Air and Water that the *York-buildings* Engine could lay upon it; and that without making the least Fracture, either in the Pipe, or the Cement that join'd the Pipes together, which has brought me to what was my next and indeed principal Aim, I mean, the Theory and Practice of Hydrostaticks and Hydraulicks: From the first of which, we learn the Motion and Equilibrium of Water and other Fluids, from their Gravity, Elasticity and Impulse, and from the latter, a Mechanical Account of those Powers, by which Water is thrown up out of the deepest Wells and Caverns, to the Tops of the highest Hills.

“ Hydrostaticks (says the honourable and ingenious
 “ Mr. *Boyle*, in his Preface to his Hydrostatical Para-
 “ doxes) is a Part of Study or Philosophy which ought
 “ to be look'd upon as the most ingenious of any;
 “ the Theorems and Problems of this Art, being
 “ the handsome Productions of Reason, and affor-
 “ ding the noblest Discoveries, not only pleasing, but
 “ also most surprizing and wonderful; in that most
 “ of the Phænomena of Nature can hardly be under-
 “ stood, without Hydrostatical Principles.” For the Il-
 lustration of which, I have made Use of those Experi-
 ments which have been laid down and explain'd by that
 Honourable Author, with others of great Note amongst
 the Learned, corroborated by an Experiment, which, in
 Honour of its Inventor, will in all Probability be cal-
 led *Torricellian*, as long as Time it self shall last.

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To go on with our learned Author, " This Art is
 " not only speculative, but practical, the Propositi-
 " ons belonging to it being very useful in Navigati-
 " on, (and that whereby the Burthen of every Ship of
 " such and such Dimensions is known) but also in all
 " other Arts and Sciences, where Enquiry is made in-
 " to the Gravities and Magnitudes of different Bodies;
 " and it is also possible, to make the Art of Hydrosta-
 " cy to be variously useful to all Professors of Medi-
 " cine and Chymistry, as that learned Author has de-
 " monstrated, in a most curious Treatise of his, enti-
 " tuled, *Medicina Hydrostatica*, &c. to which I refer
 " my Physical Reader. " And if the Study of Hydro-
 staticks is so useful in the *Materia Medica*, and to
 all Dealers in Medicine, so it is no less useful to those
 whose Office obliges them to the Practice of the *Medi-
 ca interna* itself; because, according to the excellent
Boerhaave (in his well wrote Method of studying Physick)
 a Physician ought to be well acquainted with all the Laws
 of Motion, with Staticks, Hydrostaticks, and Hydrau-
 licks, and the Properties of all Fluids, of which more by
 and by. To proceed to Vegetation, the Rising and Ascent
 of the Sap and other Liquors in Trees and Capillary
 Tubes, is not to be accounted for any other Way, than
 by Hydrostaticks; and to so great a Pitch did some
 of the Ancients carry this Notion, that they suppos'd
 (as *Bockler* has it) that they should taste of the
 Joys of Heaven, as thro' a Syphon, of which more
 hereafter.

L A T E R Philosophy is indeed much plainer, in the
 Demonstrations it gives of this wonderful Part of Na-
 ture, it being by Attraction, or in other Words by
 Pulsion,

Pulsion, (a great Principle in Hydrostaticks) it is as most learnedly hinted at by Sir *Isaac Newton*, in his *Principia*, that the Sap is made to ascend the Trunk and Boughs of Trees, and all other Vegetables, which tho' it rises much higher than by the stated Laws of Hydrostatics, it is suppos'd it will, yet it is by the Pressure or Pulsion of the Atmosphere, gravitating as it does on this lower Orb of Earth and Water, that Motion it self (with all the Actions of vegetative Vitability) owe their Existence; the Liquids being first heated and dissolv'd by the superior Influence of the Sun in Summer, and of the descending Rains which then fall, still causing a new Accession and Ascension of Matter, till the Tree reaches up to, and acquires its highest Stature. Discoveries, which have been chiefly, if not altogether owing to that angelick Genius (if I may so call him) who as he excell'd most of his Contemporaries when alive, so (may have) now dead, a superior Place in those sublim'd and happy Regions of Bliss above, as a Reward for his great Labours.

To proceed, the Laws of Hydrostaticks are no less visible in the Animal, than they are in the Vegetative Life; it being by the Gravity and Elasticity of Air, that all those Acts of Motion (on which the Circle of Life depends) are perform'd.

WERE it not for the superincumbent Air, gravitating and pressing upon, and round a Man as he walks, 'tis much to be doubted whether he could so much as stand upon his Feet; and it is plain, that it is by that Pressure of the external Air on the Muscles, that that due and regular Circulation of the Blood which contributes so much to Life and Health, has
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its Motion; for when that Pressure is taken away, the Skin (as may be seen in Cupping) distends it self, and makes it swell in the Glass; the internal Air in the Blood being (as the learned *Desaguiliers*, *Pa.* 119, of his experimental Philosophy sets down) rarified when the Pressure of the external Air is taken away; and if we look into the Inside of a human Body, we shall there find of what great Use this Elasticity of Air is.

FOR when a Man (as our oft quoted Author, *Prop.* xviii. *Pa.* 119 on another Occasion has it) by the Muscles of his Breast enlarges the Cavity of the Thorax, then the external Air (by its elastick force) finding Room wherein to expand it self, rushes in at his Mouth into the Lungs, and wherever else it can find any Vacuity, and causes that internal Motion, whereon all the Parts of Life depend; and how miserable a Thing it is, to be depriv'd of the Elasticity of that Air so rushing in, may be seen in those Animals, who undergoe the Operation of the Air-pump. This is a Demonstration of what I have before observ'd concerning the Necessity every Physician and Anatomist is under, of studying the Laws of Pressure, or the elastick or impulsive Force of Air on human Bodies:

BUT to return to what is more principally my Aim in this Treatise, as to Experiments in the common Demonstrations of Hydrostaticks, I have chiefly made Use of those, that the learned *Boyle* and *Wallis* have set forth, corroborated and improv'd as they are, by the Observations and Experiments of *Marriotte*, *Gravesande*, and others amongst the Foreigners, with those of their reverend and ingenious Translator Dr. *Desaguiliers*, by Mes-

ieurs *Watts*, *Hawksbee*, and others of our own Country, who by their ingenious Lectures have been so great Improvers of hydrostatick and mechanick Knowledge. Had even the Rising of the Water to its first Level or in other Words, had it been known, that when any Reservoir of Water laid 80 or 100 Foot, more or less, higher than any subjacent Valley, I say, that such Water, when confin'd in Pipes, would rise to very near the same Height, on any Hill on the other Side; and so on to any distant Place, as it was before: The *Romans*, (those great Sages of all Antiquity) needed not to have been at the great Expence they were, in cutting through Hills, or to have rais'd such Arches and Causeways as they did, for the Conveyance of Water upon one intire Level, from one Place to another, Undertakings so great, that no private Person could possibly attempt, much less finish; and which might have been done at a much cheaper Rate, had the Knowledge of Hydrostaticks been so known, as now it is.

THE *Vacuum* of the Ancients was a Position that in the Course of this Treatise I could not help enquiring into; a Point long held in Debate between the Philosophers of old, from *Democritus*, *Leucippus*, *Anaxagoras*, *Aristotle*, and others, to *Macedonus* *Epicionus*, *Cleomedes*, and *Hero Alexandrinus*, one of the most celebrated Writers in Hydrostaticks of all Antiquity, as they are summ'd up with great Judgment by *Bockler*, some denying there was any such Thing, whilst others as resolutely maintain'd it; some were for placing it in the first, others in the middle, but others in the sublimest Regions of the Air: Those who were for it maintaining that Doctrine (wherever the Position of it was) say that
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it was in that *inane* or empty Space, that were transacted all those Momentas, of which Fluidity is compos'd; for that, contrary to the Opinion of the Plenists, one Body could not move in another.

ON the contrary, the *Plenists* deny'd a *Vacuum* from the Impossibility there was of it, and that the Ascent of Liquors in a Syphon or Syringe was from an Abhorrence there was in Nature of any such Thing; and from thence they inferr'd, That Water might be rais'd to the greatest Height, by Means of a Syphon or Pipe, which, as they had seen, in small Experiments of Wine, Water, &c. might be easily transferr'd from one Valley to another: And so long was this Error continued, that I have seen a Book of Machines written, even in Queen *Elizabeth's* Time, by one *Ward* an Engineer, who ventur'd to give a Sketch of a high Hill, (and a House at the Bottom or Side) over which, by a vast extended Syphon, the Water was to be convey'd from one Vale to another.

BUT in Answer to this, *Gallileo*, a very ingenious Author amongst the *Italians*, was the first which found out (as the learned *Wallis*, *Cap. xiv. pro 14. Pa. 743.* of his *Hydrostaticks*, has it) that this *Fuga vacui*, or this Abhorrence which there was suppos'd to be in Nature, of a *Vacuum*, was not infinite, but circumscrib'd within certain Limitations, and substituted in the Room of it the *Equipondium*, or *Equilibrium* of Air, pressing or gravitating upon other Bodies, especially Water, which caused the Water, when the Air was suck'd out, and the Ballance lost, to ascend the Pipe, Pump, or Tube; from which some Moderns have divided this *Vacuum* into a *Vacuum disseminatum seu in-*

terspersum, and into a *Vacuum coacervatum*, of which more in its proper Place: And to go on, this Thought of *Gallileo's* was much improv'd by *Torricelli* his Successor, in an Experiment of his, which is already hinted at, and which has put this Matter beyond all Dispute (I mean the Barometer) where he found by comparing the Weight of Water with Quicksilver, which is Fourteen Times heavier than Water, that Mercury or Quicksilver would not rise above 28 or 29 Inches, and consequently Water not above 32 or 33 Foot at most; and indeed by what I have observ'd, amongst our Engineers, and Machine or Pump Makers, there are few that will rely upon the natural Ascent of Water, by the Pressure of the Atmosphere, so high as that, and therefore generally fix their Suckers, at about 25 or 26 Foot above the Surface of the Water; tho' several Experiments in Hydrostaticks inform us, that the lower you go in a Well, the higher the Quicksilver (and consequently the Water) will rise; and the higher you ascend towards the Top of any Hill, with the Barometer in your Hand, the more the Quicksilver will fall. From all which, our modern Philosophers have inferr'd (and that with great Reason) that what the Ancients call'd the *Fuga vacui* (*Gallileo* first leading the Way, and who was afterwards follow'd and improv'd by *Torricelli*, *Boyle*, *Wallis*, and a great many others) was no other than the Pulsion or Pressure of external Air, gravitating on the Surface of Water, which could make it ascend only to about 32 or 33 Foot high at most; tho' the Ancients, by Mistake, thought that they could make it mount to 200 or 300 Foot, by their imaginary *Fuga vacui*

vacui (as has been before noted): And this Obscurity in the Ancients was in a great Measure owing to the imperfect Idea they had of the Gravitation of Fluids one upon another, and of the Elasticity, Dilatation, and Compression of Air, whose Effects are now so clearly demonstrated in all modern Calculations and Experiments.

As to the *First*, I mean the Gravitation and Pressure of Fluids one upon another, and of every Particle of any one Fluid upon that which is under it, that is clearly prov'd, not only by *Archimedes*, in Two excellent Books of his, *De insidentibus Humido*, in opposition to the *Peripateticks*, who would not allow of such a Gravitation, at least *That Water would not gravitate on Water, nor Air on Air*, but also by the honourable and ingenious *Boyle, Wallis*, and others; and yet more particularly by *Ozanam, Marriotte, Gravesande, &c.* as they are judiciously explain'd by their reverend and learned Translator, Dr. *Desaguiliers*, even beyond all Dispute; which has also been the Occasion of several select Tables, to be found in Sir *Jonas More's Compendium, Ozanam's Cursus*, the Transactions of the Royal Society, and the like Places.

And this Gravitation of Fluids one upon another, according to their respective Weights, must be own'd to be one of the greatest Momentas in all Hydrostatick Knowledge, *The Weight of unknown Bodies being found out, by the Weight and Capacity of those that are known*, as was that of King *Hiero's Crown* so judiciously discover'd by *Archimedes*, as he was bathing himself in Water: Of which more in its proper Place.

THE Weight of Air is not the least, in the Discoveries that have been made in Hydrostaticks; for who amongst
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the Ancients could have thought that Air (thin and subtile as it is) should ever have been reduc'd to Weight and Measure; yet so it is, that from undoubted Experiments it is found, that a Cylindrical Column of Air, whose Diameter is seven Inches, and its Length a Yard, weighs about one Ounce *Averdupois*: Nor will this be judg'd a needless Speculation in Hydrostaticks, when we treat of the Impulse of Air against the Sails of Windmills, &c. if to it be added what *Marriotte*, and from him the Reverend and ingenious Dr. *Desaguiliers* have from Experiments set down, that though the Weight of Air is so much less than that of Water, yet its Velocity is greater: So what was wanted in the Gravity of one, was fully made up in the Elasticity and Impulse of the other.

AND as it is chiefly owing to the Industry of our modern Philosophers, that these and other wonderful Discoveries relating to Air are found out; I mean as to its Gravity, Elasticity, Rarefaction, Condensation, and other Dispositions of the same Nature just now recited; so also in Water, there are a great many Discoveries of the same kind; it being to the Labours of the illustrious *Boyle*, we owe the Knowledge, that 13,000 Particles of Water may hang upon the Point of a Needle, that one Drop of Water is divisible into 26 Millions of Parts, and that a Cubick Inch contains 13,300 Millions of such Vapour. Had this been rightly understood by the Ancients they need not have laboured so long under the mistaken Notion that Water so expanded could find Room enough for such sudden Transmutations, which they imagin'd were perform'd in the Bowels of the Earth for the regular Supply of all Perennial Springs.

B U T

The PREFACE

xv

BUT to return to the farther Account of this Elasticity of Air, from which this last Paragraph is a kind of Digression, 'tis there may be seen a wonderful Work in Nature, and without which there would soon follow a Stagnation, and consequently an Annihilation of all sublunary Things; and that contrary to the Opinion of the *Plenists* and *Vacuists*, those Enemies to Reason, it is so made as to recede and give Place to all Bodies whatsoever, which are more Weighty and Ponderous than it self, returning afterwards to its first Position, and maintaining its fluctuating Motion; and that it should at the same Time be capable of Dilatation and Compression to such an infinite Degree, is what at first Sight seems impossible; Discoveries which have had their Rise chiefly to the Industry of the last Century, and to the immortal Honour of the *Royal Society*, and its noble and ingenious Professors: Nor will that excellent Discourse of the Honorable Mr. *Boyle* against *Linus*, *Hobbs*, &c. on this Subject, be, tis hop'd, ever forgot, as long as good Literature has any Being in these Kingdoms.

WHO amongst the Ancients (and indeed some Moderns) could have thought that Air could be dilated beyond its ordinary Capacity, as 13,769 is to 1; and that it could be compress'd as 40 to 1; so that the Difference between expanded and contracted Air, is as 550,760 to 1; or by a running Number, as 550,000 at least; let me give it in the learned *Wallis's* own Words, *Ut Quinquies Centena & quinquaginta Millia, ad unum, & quanto, per Media olim forte Excogitanda. Removeri adhuc possit ab invicem uterque Terminus conjicere non valemus. Vid. Wallis, De Hydros. Prop. 13. Cap. XIV.*

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THIS Dilatation and Compression of Air beyond and within its natural State, points out the great Mistake of *Aristotle* and his Followers, who imagin'd that Springs have their Rise from Air which is condens'd in the Bowels and large Vaults of the Earth: Air being to Water proportionably, as 800 to 1. The Water then rising in the River *Seine*, as described by *Marriotte*, must have a Cavern of Air to supply it (could there be such a sudden Transmutation of Elements) of 160,000 Cubick Feet to supply it a Minute, of 9,800,000,000 Cubick Feet to supply it an Hour; and of 220,400,000,000 Cubick Feet to supply it 24 Hours, or a Day natural; and 571,620,000,000,000 a whole Year; where any such are to be found, there is no Body which I ever heard of, that knows; for this last, being reduced, produces upwards of 3000 Cubical Miles, to such great Absurdities are those Things carryed, whose Demonstrations are Philosophical and Speculative, rather than Mechanical.

BUT should we for once admit that there can be such a sudden Transmutation of Air into Water, and which possibly might be transacted in so short a Time as a Minute, (tho' that is an Allowance infinitely wide of Truth) such a Receptacle ought to be 500 Foot cubical; and if they were to be divided into 8, 10, or 12 Parts, their Capacities would be infinitely larger than any one that was ever yet seen or met with for that Purpose, at least that have fallen in the Compass of my Observation.

To proceed, the Gravity, Elasticity, Compression, and Dilatation of Air and other Fluids, is a Subject, that if traced through all its various Circumstances, is
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most wonderful and amazing, from whence and however situated, or of what Parts this Elasticity is composed: I shall, with the learned *Wallis*, not spend much Time in delineating; some say of it, That it consists of innumerable Quantity of Threads or Fibres, and have compar'd it to a Fleece of Wool, or perhaps more properly to a Lock of curl'd Hair, which you may compress in your Hand; yet after that Compression is over, it will, like a Spring, return to its former State again; but others, not pleas'd with this Definition, would rather suppose, that Air is compos'd of an infinite Number of Corpuscles, or little round Bodies, which, by the Laws of Motion, jostle and recede from each other, giving Place to all heavier Bodies whatever, which come in its Way; and after that, return into its Place again.

Wallis says, That there is a Kind of Elasticity, even in Marble, Earthen Ware, and in innumerable other hard Things, which is discoverable by their Sound, when struck with a Hammer, or any other Instrument; but that in Fact there is no Account of Elasticity, so plain as that of a Steel Sword, which though bent a considerable Time, will, especially if it be touch'd with a Loadstone, unbend it self again: Nor does he forbear to ascribe a certain Degree of Elasticity even to Lead it self; but the greatest Instance of Elasticity (if I may so call it) that I have ever observ'd, is that of mill'd Lead, which being compress'd to a great Degree in its Passage, between two Rows in the Mill, that all the Pores are so clos'd, as that one would believe they would never retract again; yet upon its Exposure to the Sun and Air, those compress'd Parts will tear and dis sever from one another, being impatient of

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that Imprisonment, and to endeavour to assume as much as possible its natural State again; to use the Words of the learned *Wallis*, in an Observation of this Kind: *So great is the Affection, even of inanimate Beings, to return to that Position, in which Nature, or rather God Almighty, the great Author and Architect of the Universe, first plac'd them.*

THE Impulse of the Air, and other Fluids (of Air especially) is next to be consider'd, being a Subject of that Use in Hydrostaticks, as well as Hydraulicks, that I have been from the laborious *Marriotte* very particular in it; since 'tis on this, that the Celerity of the Wheels, and the cylindrical Weight of Water that they can raise or drive, that all Calculations in Engine Work (especially Wind-mills depends,) which may either go too fast or too slow, as the Impulse of the Air or Wind is: Nor is it of less Use in Water Engines, where there is but a little Water to drive the Wheel, (as it often happens,) and where the great Waste and Expence of it (were we to put on more than there is really Occasion for) would prove of very ill Consequence. In the Theory of this, we shall also find some very curious Observations in Nature, which, when reduc'd to Practice, may be of very great Service in several Parts of mechanick and philosophick Experiments. And thus have I given a short Account of what is to be expected from the second Book of this Volume, which treats of Hydrostaticks. I proceed to

THE third Book, which is particularly apply'd to Hydraulicks, a Part of mechanick Knowledge so very useful, that no Body should be without it, though it must be confess'd, it is generally not so well understood

stood as it might be, except by some few Workmen: Nor were the Ancients, as will appear by the Course of this Treatise, acquainted with it all, at least not in such a Manner, as that they could thereby raise what Water was wanted to any great Heights, or well drain any Mine or Cistern that lay so deep as now we do: Those describ'd by *Vitruvius*, and others amongst the *Romans*, being mean and trifling, in Comparison of those, Engineers now produce.

'Tis to *Archimedes*, *Aristotle*, and others amongst the Ancients, that we owe those Principles of Staticks and Mechanicks, that naturally lead to the Practice of the Subject we are upon, improv'd as it has been by *Wallis*, and some other latter Writers; so that the practical Part of it has receiv'd most considerable Additions to it, from *Hero Alexandrinus*, *Bockler*, *Sir Jonas Moore*, *Sir Samuel Moorland*, and other Authors of undoubted Repute in the two last Centuries; and may I not add, for the Honour of the present Age, and that which is just past by, we have or lately had our *Sorocolds*, *Saverys*, *Desaguliers's*, *Hollands*, with a great many others, of great, as well as inferior Note, who have brought the Practice of Engines into great Use: But it must be own'd at the same Time, that how greatly soever Gentlemen and others, that have often Occasion of these Things, are vers'd in the Theory; yet the Practice is somewhat difficult, nor is it so well known to them, as to judge when they are well or ill us'd, or whether their Undertakings are likely to succeed or not.

THE Scyphon is the first Machine I have endeavour'd to describe and improve, and also what Conclusions may be drawn from small Experiments, (as decanting

canting of Wine, &c.) for the Benefit of those which are arger; and here I have taken in the most material Experiments of *Gravesande*, *Marriotte*, *Desaguiliers*, and others, who have put its Uses beyond Dispute.

THE Second Instrument I have at large describ'd, is the Limace or Skrew of *Archimedes*, with which, it is said, he drew off the great Inundations of *Egypt*, when the *Nile* transgress'd its Bounds, and is now indeed little other (though perhaps somewhat improved) than what is so much magnified in the draining off Fish-Ponds, &c. where the Current is too dead to carry it off by Nature.

THE *Antlia*, or Pump of *Cetsibus*, so much fam'd by the Ancients, (and so much better understood and improv'd by the Moderns,) is certainly the Mother of all Hydraulick Machines; in the Explanation of which, I have endeavour'd by Drafts and otherwise, to demonstrate its Uses, and the several best Kinds of which it is composed.

I then proceed to compound Engines, (after a short View of the Chain Pump so much improved by Mr. *Holland*) and take along with me their several Kinds, whether in Crank or Chain Work; or which is now more in Use, the vibrating Leaver, drove as they are all by Wind or Water, by Overshot, Undershot, or Horizontal Wheels; in all which, I must own my self much indebted to the ingenious *Bockler* in his *Theatro Machinorum*, as well as to the Improvements made by Mess. *Sorocold*, *Aldersea*, *Newsham*, &c. Nor shall I stop here, but with some Pains and Expence procure the Plans Profiles, or Perspectives of some of the best Engines

Engines now in Use, with their Descriptions and the like, that so I may perfect what I intended under this Head.

LASTLY, and to conclude this third Book, I have given a full and ample Account of the Fire Engine, the Invention of my late worthy and ingenious Friend Captain *Savery*; an Invention of that Ingenuity and Use, if I may be allow'd to use the Words of the laborious *Harris* in his *Lexicon Technicum*, that it may be justly accounted one of the greatest Pieces of Art, that perhaps this or any other Country has yet produc'd; this together with the Improvements made by Mr. *Newsham*, &c. as also an Account of Engines for draining Fens, putting out of Fire, driving of Mills, which finishes this 3d Book.

THE last Book of this Treatise, and which is indeed the Sum and Corollary of the former three reduc'd to Practice, is concerning the Quantity of Water that comes in from Springs or Engines, and the Expence thereof, in Fountains, Canals, Cascades, &c. deduc'd not only from the Experiments of *Marriotte*, but from the known Quantity that several Engines and Springs give, corroborated by Practice and Experience.

BUT as the chief Principles and Experiments of this Part of Hydrostatick and Hydraulick Knowledge are deduc'd from *Gallileo*, *Torricelli* and others, who have made some Essays towards it in their invaluable Tracts of the Acceleration of Bodies; and as the whole has been enlarg'd upon and explained by few, except *Marriotte* and his Rev. and Ingenious Translator, I have found my self at some Loss how to reduce it to *English* Practice, the Difference between the Measures of *England* and *France*, being greater than at first View they may appear to be; so that an *Englishman* who goes about to calculate

calculate by the Pint, Gallon, Muid, or any other Measure of *France*, compar'd with those of our own Country, would find himself greatly at a Loss to come at the Truth of his Calculation.

I need not enumerate, in this Place, the Methods I have taken to reconcile these two Kinds of Measures (which are so necessary to be known) one to another, for the Explanation of the curious Examens of our oft-quoted Authors, on whom every Body relies for the Theory of this useful Part of Mechanical Knowledge: Because that will appear more plainly in the Course of the ensuing Treatise, and would have been too long to insert here; but the Reader may take it for granted, that I have (with as much Exactness as I possibly could) regulated and compared them both together; constantly retaining nevertheless so much of the *French* as relates to the Diameter of the Pipes of Conduit, Adjutages, or Holes through which the Water spouts; because I supposed that the endeavouring to alter them, would still make my Calculations from *Marriotte* the more difficult; when I have Occasion therefore to mention an Adjutage, Pipe, or Bore of an Inch Diameter, I would be understood still to mean that of the *French* Measure, which is in single Numbers to the *English*, as 16 is to 15, or when superficially taken, as 256 is to 225, or farther, if solidly taken, as 4096, is to 3375.

THE chief Additions I have made to this Part of my Undertaking is, as has been above hinted at, an Account of the several Rules in Arithmetick, as also Tables of the several Weights and Measures of *England*, as fix'd by Statutes, and Acts of Parliament, and Excise, compar'd with the *French*, preceding the Practical Calculation

culatation of the coming in, and the Distribution and Expence of Water in Villa's, Cascades, &c. which Tables I have enlarg'd from *Marriotte*, and have also given Rules for the Thickness of Lead in Pipes of Conduit or otherwise, which was not done by *Marriotte*, whose Calculations were without doubt for Copper.

THEN in the last Place, I have added some Tables of the Cylindrical Weight of Water, that must of Course be on all Engines in the raising it to great Heights; which when added to the Friction that must necessarily arise from the great Length and Distance of Pipes, together with the progressive Addition that is in every determinate Number of Yards, in the raising of Water to those great Heights, will make the Load that lies on the Tail of a Mill Wheel, (and which ought to be well understood) to be as it were immense.

THUS in a Pipe of Conduit of 4 or $4\frac{1}{2}$ Inches Diameter, which is often the Size of a Pipe for the raising of Water 100 or 120 Foot high, I say in such a Case, and where the Water runs a great Way, as suppose 15 or 1600 Yards, the Cylindrical Weight of Water encreases to a very great Degree.

IT will be found by those Tables, that in every Yard running of Pipe (being 7 Inches in Diameter) there is 57 l. 5 oz. $\frac{95}{100}$ Averdupois Weight; or to give it in Fractions for the more exact multiplying of it, there is 917 oz. 95481 pts, which when multiplied by 1600, the Number of Yards in the supposed Length, the Answer is 91795 l. 48100 parts, which is being reduced to Hundred Weights of 112 l. 817 l. Weight, and 91 l. which added to the Friction and the progressive additional Weight that happens in such great Lengths
and

and Heights, such a Wheel cannot sustain less than 1200 *l.* Weight, were it suppos'd to be ty'd to the Tail thereof; so well worth the while are Calculations of this Kind, for the Discovery of what Strength the Wheel and all other Parts of such a Machine ought to be; and also the Quantity and Expence of Water necessary to drive it, and supply the Pipe of Conduit at the same Time: Nor have I taken this altogether from Theory, but from Practice and Experience it self, as it is found in some of the best Engines that have been erected in this Part of *Great Britain* as before noted.

AGREEABLE to this, I have not been satisfied in what *Marriotte*, and others have said of the coming in of Water (especially from Engines) and that for the Reasons abovemention'd; for tho' the coming in of Water from a Spring, where the Distance is not great, and where the Water is not to pass over Hill and Dale, may by its regular and uniform Motion produce the Quantities it is generally estimated it will, yet the Interspace there is between the Stroke of every Piston, supposing there are 2 or 3 (for more are not necessary) added to the Friction which is in great Lengths, no certain Rule can be laid down, rightly to determine one's Practice.

To this may be added, what an ingenious Gentleman, and curious Observer of Works of this Nature has remark'd; (*viz.*) that the Interposition there is of Air (notwithstanding the putting in of Wind-cocks) called as it is by Workmen (the *Wind Boundedness* of Pipes,) is more or less, according as the Shell of the Pipes of Conduit are larger or more or less solid or porous; thus Elm Pipe, being porous, gives way for the Air, which is
I naturally

naturally compress'd by the more solid and closer Contexture of Iron, Lead or Earth, all which makes a considerable Alteration in the Quantity of Water which Engines produce.

BESIDES, the ingenious Translator of *Marriotte*, in Conjunction with the Reverend Mr. *Lowthrope* (who was well-knowing in Works of this Kind) says, from Experience Pag. 289 of *Marriotte's* Hydrostaticks; that altho' through a Hole of 1 Inch $\frac{5}{8}$ which according to our *French* Author ought to give nine Tun of Water in an Hour; yet at the Distance of 1400 Yards through a Pipe of that Bore which went all the Way, it did not give above five Tun in an Hour; and what was surprizing in Experiments of that Nature, was, that the Quantity of Water diminish'd rather in Proportion to the Length it did run, than to the Friction on the Sides of the Pipes; for if a seven Inch Pipe (say those industrious Experimenters) and a three Inch Pipe run the same Length, as for Example a Mile; the Deficiency will not be on Account of the Friction, but nearly in Proportion to the Quantity of Water that each Pipe ought to give, which is also confirm'd by all the Calculations I have been able to make from these and other Experiments, and is a Confirmation of what the ingenious Gentleman I have just now nam'd has observ'd on this Head.

By the same Rules also that we calculate the coming in of Water, we calculate the going out or Expence of it, in Cascades and Fountains, with this Difference; that where the Water goes down a Cascade, or spouts out through an Adjutage or Pipe of Conduct, where
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the Fall is regular, and the Height of the Reservoir and Pipe of Conduct proportionable; there the Water is more certain in its Expence than it can be in its coming in, under the Circumstances beforemention'd, except it be from a Spring or Reservoir which lies near at hand, and where the Motion is uniform, constant and regular.

THE last thing, and which is indeed the Corollary or Result of all the rest, is some Designs of Grotto's, Canals, Cascades, Basins, &c. in which Water is shew'd to the best Advantage, and in a more natural easy Manner than is usually practis'd; because it is for want of this cheap and easy Way, that I judge many great Designs have not had Water brought to them, nor explain'd as it ought, I mean to that Expence that too often is in fine Grotts, Caves and Cascades.

I remember some few Years ago to have seen in *Holland* a very fine one of the first Kind, which tho' not above 12 or 14 Foot wide cost eleven hundred Pounds, set as it was with costly Shells and other glittering Works, which made it appear like a tinsell'd hobby Horse, rather than a Work of Nature; and there are now in *England* some Works of this Kind, tho' something rougher, that came to four or five hundred; tho' I am persuaded that as 'tis a known Maxim, *That the nearer we approach Nature the better it is*; so a rude grottesque Piece of Work of this Kind may be done for less than a Hundred, since tis not in the Beauty of the Materials, but the Proportion of the Work, that this and most other Works in Architecture consist.

THE same thing I have observ'd in Cascade Works, which are generally made so smooth and fine that the
Water

Water is not broke to Pieces in its Fall, and consequently the Beauty of it is greatly lost, tho' at the same Time the Expence has been immensely great, as is visible in one or two noted Places of this Kind; but this I have endeavour'd to remedy by some more rural and grotesque Designs.

AND thus have I given as succinct an Account as I can, of the Purport of the ensuing Treatise, in the Course of which I have all along paid all the just Acknowledgments which are due to the Labours and Writings of those, both among the Ancients and Moderns, who have gone before me, even from *Aristotle* and *Archimedes*, *Democritus*, *Leucippus*, *Anaxagoras* and others amongst the Ancients, to *Macedonius*, *Epicinonius*, *Cleomedes*, *Vitruvius*, *Hero Alexandrinus* and others of their Successors. As also to *Gallileo*, *Torricelli*, *Boyle*, *Wallis* &c. amongst those which are of a more modern Date. To give a short Account of them,

Aristotle was a well know Philosopher, Master of *Alexander* and the *Peripateticks*, who as he wrote of almost every thing, 'tis no Wonder he should be mistaken in some, as he certainly was in the Original and Rise of Springs, the Gravitation of Fluids &c. He wrote several Books in Mechanics, and was undoubtedly a great Proficient in the Principles of that Science.

Archimedes was a greater and more solid Mathematician than any which wrote amongst the Ancients (not excepting *Euclid* himself) he was an Inhabitant of the ancient *Syracuse*, and was as some say knock'd on the Head whilst he was busively employing himself in drawing Lines for its Defence there are two Books of his now extant which relate to Hydrostaticks, and

which are publish'd by Bishop *Barrow* (amongst many other of his Works) entituled *de Insidentibus Humido*, to which I have had recourse in this Treatise.

HE was the first that discover'd the specifick Gravities of different Bodies, which, as the Story says, came into his Head when he was in the Bath; because having observ'd that his Body rais'd the Water in Proportion to the Room it took up, he guess'd that by that Means he might easily find out whether there was any Silver mixt in King *Aiero's* Crown, by finding by the different Weights of each, how much more Gold press'd upon the Water more than silver did.

Democritus, *Leucippus*, *Anaxagoras*, and others before nam'd were all of them Studiers of Hydrostaticks, but wrote differently one against another, and maintain'd with great Vehemence the Disputes which long subsisted amongst them, concerning the *Vacuum* and *Plenum*; whose Opinions are all judiciously sum'd up by *Bockler* in one of his Treatises of Hydrostaticks, which is now easily to be had in any of the Booksellers Shops.

Vitruvius is an Author too well known for me to enlarge on his Character, but who (amongst others of his elaborate and ingenious Writings) has distinguish'd himself well in Hydrostaticks or Water-works, especially the Method practis'd amongst the *Romans* in the Conveyance of their Water from one Place to another, and of the Engines at that Time in use.

Hero Alexandrinus is the next I shall mention on Account of his great Skill in Hydrostaticks, and whose Writings are all or most of them now in print, and abridg'd by *Bockler* and others; by all which it appears
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that this elaborate Author had not found out the real Ascent of Water in Tubes or Pipes of Conduct, but that he labour'd under, and was as it were cruciated between the so much contended Disputes of the Vacuists and Plenists.

Gallileo and *Torricelli* were of later Date, being Architects to one of the Great Dukes of *Tuscany* successively one after another in the 15th Century. *Gallileo* was the first that destroy'd the Notion of a *Vacuum*, and that found out that the Ascent of Liquids in Tubes was from an Equipondium of Air pressing thereon, and not from the *Fuga Vacui* so much talked of, and this was much improv'd by his Successor in the Barometer which is always like to carry his Name.

THE learned *Boyle*, *Wallis* and others, were (as they had great Reason) tight Sticklers for this Opinion, as was *Morinus*, *Ghetaldus*, *Stevinus* and others mention'd by Mr. *Boyle*, and also against that Opinion of the *Peripateticks* which maintain'd *Quod Aquam non gravitare in aquâ; nec aerem in aere.*

THIS the learned *Boyle* has, in Conjunction with *Wallis*, sufficiently refuted, and also have from the first Principles of *Archimedes* sufficiently explain'd these great Principles in hydrostatick Knowledge. The first of these learned Authors was (as he himself hints at) attack'd by a bold north *Britain* whom he does not name; but I take to be one *Sinclair*, who has also wrote a Treatise on Hydrostaticks, which is now to be had in some Booksellers Shops, but this was but a short Dispute in Comparison of that which he maintain'd against *Hobbs* and *Linus* concerning Air, which is also bound
up

up in his Works. This noble Person was too great a Man for me to attempt to draw his Character.

Wallis was a Cotemporary of his, and was by much a too hard headed Man for any of his Antagonists, as History and many other of his Works do evince.

Marriotte, *Gravesande*, *Plot Hooke*, &c. are all of them Followers of the eminent Authors I have just now nam'd, tho' the two first has with the Assistance of their Translator much improv'd upon the other Authors; nor must Dr. *Keil* the ingenious Professor of Astronomy in the University of *Oxford* be forgot on this Occasion.

HAVING thus paid a short Tribute to the Memory of those great Men who are dead, at least absent from us, I come to make my just Acknowledgments to those of the Nobility, Gentry, Clergy, and Artificers now alive, who have been assisting to me in this Work. And here I must acknowledge the Favours receiv'd from the Reverend and ingenious Mr. *Samuel Lindsey* Chaplain to the late Lord and Lady *Brooke*, who pointed out to me all or most of those Books from which I have extracted this Work. To the Works of the Rev. Dr. *Desaguiliers* it is I in a great Measure owe all that is valuable in it, nor can I pass by in Silence the good Will express'd to me by the ingenious Mr. *Mills* chief Surveyor of the new River Company, whom I have Occasion to mention anonymously in several Parts of the following Treatise.

ONE of the last things I have to do in this Preface is to beg the favourable and candid Construction of all those Noblemen and Gentlemen who have encourag'd this Undertaking, and are pleas'd to give themselves the Trouble of reading it. The Errors are not I hope

large nor many, but in the Hurry in which my other Business is, 'twas impossible to avoid some (tho' 'tis hop'd few) of those Erratas, which are incident even to those who have much more Leisure than I have; such as erroneous Concords, Mispointings, and the like. For it has so happened, that the Proofs having been sent to me in the several Countries where I have been in my Employ, I had neither the original Copy, nor so much Leisure as I could have wish'd for to correct the Errors of the Press; but was forced to depend on Strength of Memory; and this may have occasion'd some little Errors in the Quotations I have made from ancient Authors, all which, (if any,) all good natur'd Readers will, I hope, correct.

ANOTHER Difficulty I labour'd under (during the writing of this Treatise) was, that being in the Country I wanted the Assistance of many original Authors, from which I might have drawn (with more Ease and Certainty) what I have in this Treatise set down, than I could, not having them in my Possession; the greatest Help that I had being out of the Library (tho' as yet unfinished) of my very worthy learned and noble Friend and Master, the right honourable the Earl of Orrery, at his Seat at *Marston* in *Somersetshire*: But that noble Lord's Collection in that Place being far short of what he intends, I could not be fully supply'd there. The being so far distant from *London* was then a great Bar to me likewise, from conversing with such ingenious and learned Men as might have help'd me on personally, in this laborious and useful Work.

LASTLY I beg Leave to add a Word or two of the Reasons why I have chose to call the following
Treatise.

Treatise an Introduction to, rather than a general or compleat System of Hydrostaticks and Hydraulicks; which is in short from the Largeness and Extent of the Subject, and from the Diffidence I was under of going well through so great an Undertaking; the chief of my Aim being to reduce the most material Parts of these Sciences into one Volume, which may, 'tis hop'd, induce some more able Pen to give a finishing Stroke to a Work so diverting in itself and so beneficial to Mankind.

TILL that is done, the good natur'd Part of the World will ('tis humbly hop'd) excuse my Presumption in aiming at so great a Work as this is, the Paths of which so few have trod before me (especially in the comprehensive Manner in which this is endeavour'd to be drawn); this added to the Diversion I have had in compiling it, and in taking (tho' but a transient View,) of some of the most wonderful Phænomena's of Nature, will sufficiently recompence the Pains I have been at, and set me above the little Cavils of mercenary and pretended Wits.





THE CONTENTS.

VOL. I. BOOK I.

Chap.

1.  Concerning the Water-works of the Ancient Romans, French, &c. Page 1
2.  Of the Origin and Rise of Springs, and of the Opinion of those who ascribe them to Air, Vapours, Dews, Rain, Snow, &c. 14
3.  Of the Opinion of those, who with more Probability, attribute the Original and Rise of Perennial Springs to subterraneous Causes, &c. 32
4. Of irregular Springs, and the Method by which they are transmitted to the Surface of the Earth, and lose their saline Properties 63
5. Of the Method of discovering and searching for Springs; their specifick Qualifications, and the like 76
6. Of the Instruments proper for, and Method of taking the Levels or Falls of Water from a Spring-head, to a Mansion-house, Building, Reservoir, Garden, Pond, &c. and the Allowances to be made in Levelling, for the Curvature of the Earth, Descent of the Water, and the like 84
7. Of the proper Methods to be taken in the adjusting the Levels or Falls from a Spring-head, so as to conduct them by a gradual Descent to the House, or other Place required 102
8. Of the conducting of Water by Aqueducts, Drains, &c. 110
9. Of the several Kinds of Pipes for the Conveyance of Water, whether Lead, Iron, Earth, or Wood 115

f

1c. Of

The CONTENTS.

Chap.

10. *Of Reservoirs, Basins, &c. the Method of making them, their Construction, proper Extent, Depths, and other Dimensions* Page 127

BOOK II.

11. *OF Hydrostaticks, its Etymology, Definitions, &c.* 129
 12. *Of the Gravitation of Fluids, according to the Honourable Mr. Boyle* 140
 13. *Of the so much disputed Vacuum of the Ancients, and of the natural Effects of Air, and other Fluids in Hydrostaticks* 165
 14. *Of Air and its Effects in Hydrostaticks, by its Gravity, &c.* 184
 15. *Of several Instruments whereby the Principles of Hydrostaticks are more fully explain'd* 196
 16. *Of Air, and its Effects in Hydrostaticks, by its Elasticity: As also, of its Dilatation and Compression* 220
 13.* *Of the Impulsive Force of Air, and other Fluids in Hydrostaticks* 252
 14.* *Of the different Impulse or Fluctuation of Water in a Mill-Pond or River, for the driving of Mill-Wheels, varied according to the different Circumstances which attend the Fall of it* 261
 15.* *Of Mill-Wheels for raising Water, &c. their Dimensions, Strength, Position, and the like; and also the best Places for setting of Mills* 272

. N. B. By Mistake of the Printer, 14, 15, 16, with this * Mark, were printed in the Place of 17, 18, 19.

VOL. II. BOOK III.

20. *OF Hydraulicks, its Etymology, &c.* 275
 21. *Of the Mechanick Sciences, and their Uses in Hydraulicks* 279
 22. *Of the Siphon, and other artificial Fountains and Jets of Water* 294
 23. *Of the Antlia or Pump; its Description, Uses and Kinds, &c.* 298
 24. *Of the Chain-Pump* 313
 25. *Of* 313

The C O N T E N T S.

Chap.	Page
25. <i>Of Crank-Work, and of regulating Engines</i>	316
26. <i>Of the Crank-Work, vibrating Leaver, and complicated or Treble-Wheel Engine for raising Water</i>	318
27. <i>Of the vibrating Leaver and Crank-Work Engine, with a single Wheel only, to give them Motion</i>	321
28. <i>Of the Engine for raising Water by Fire</i>	325
29. <i>A Description of the Engine to raise Water by Fire, fixed in a Frame of Timber, instead of the usual Engine House, as improved by Mr. Newcomen</i>	336
30. <i>Of several Machines for the playing of Musick</i>	343

B O O K IV.

30. <i>A General Introduction concerning the coming in of Water from Engines or Springs, and the Expence thereof in Cascades and Fountains</i>	353
31. <i>A farther Calculation of the coming in of Water from Engines, or otherwise</i>	359
32. <i>Of Friction, its Etymology, and the Effect it has on Pipes of Conduet, &c.</i>	365
33. <i>Of the several Rules in Arithmetick, of which a Learner in Hydrostaticks ought to be informed</i>	373
34. <i>Of several Weights and Measures necessary to be known, for the better explaining the Division, Distribution and Expence of Water</i>	379
35. <i>Of Artificial Fountains, Jets d'Eau, &c.</i>	391
36. <i>Of the Construction and use of a Gauge for measuring of Water, and of the Distribution and Expence of it to Cities, Towns, Gardens, &c.</i>	398
37. <i>A Description of the Thirty last Plates</i>	402

ERRATA.

Preface *Page* 1. *Line* 5. for never read neither. p. 10. and p. 26. for Epicononus read Epiconous. p. 20. l. 13. for Cetfibus read Ctesibius. p. 21. l. 11. for Newsham read Newcomen. Chap. 1. p. 2. l. 39. for Ittan read Ittau. p. 13. l. 38. for Durham read Denham. p. 22. l. 3. for Nieuentyt read Nieuwentyt. p. 23. l. 15. for 2380500 read 238050. p. 25. l. 1. &c for Deerham read Derham. p. 28. l. 29. for higher read lower. p. 29. l. 18. read don't contribute much. p. 37, 49, 66, 76, 82, 103. for Varennius read Varenius. p. 119. l. 17. for Thyrlc Ernby read Kyrle Ernly. Notes Book II. p. 4. Col. 1. l. 19. for A B read A H. Fig. 4 Tab. 6 *Ibid.* l. 21. for D. E. read G. I. p. 214. l. 34. read, It has been objected by the Enemies of the Barometer, that the slow Ascent of the Mercury adds nothing to the positive Discovery of the future Serenity of the Weather. p. 257. for Fig. 3. Tab. seq. read Fig. IX. *Ibid.* for Fig. 8. read Fig. X. p. 263. l. 32. for E F read H F. and l. 42. for Fig. 11. read Fig. 10. p. 269. l. 6. for Fig. 5. read Fig. 13. and l. 24. for Fig. 6. read Fig. 14. p. 270. l. 2. for Fig. 5. read Fig. 13. p. 271. l. 2. for Fig. 5. Tab. sequentia read Fig. 13. Tab. preced. p. 355. l. 38. read Plate V. p. 368. p. 357. for Fig. 1. Tab. seq. read Fig. 3. p. 368. p. 362 l. 12 for 8 Diameter read 12 Diameter. p. 363. l. 3 read 12 for 8 Diameter. p. 367. l. 14. for Fig. 1. Tab. seq. read Fig. 1. N. 2. Tab. seq. In the Notes, p. 108. for it will pass freely, read it will not pass freely.



DIRECTIONS to the Bookbinder.

- I. Place the Title of the second Volume before **BOOK III.**
Page 275.
- II. Place the Cuts marked *Page* 352 at *P.* 350.
- III. Place the Contents after the Preface to the first Volume.
- IV. Place the 30 last Cuts at the End of the 4th Book, before the Notes.
- V. Place the Notes of the 2d Book after *Page* 274: which ends the first Volume.



A N
INTRODUCTION
T O A
General S Y S T E M
O F
HYDROSTATICKS and HYDRAULICKS.

BOOK I.

C H A P. I.

*Concerning the Water-Works of the Antient Romans,
French, &c.*



T would be needless for me, in this Place, to entertain my Reader with any long Account of the great Use and Beauty that Water (whether brought by Engines or otherwise) contributes to a Country Seat, as well as Cities and Towns ; Examples of which every Day's Experience, as well as the Accounts received from Abroad, do sufficiently evince.

B

That

That, as to the Uses of it, it is undeniably the Axis on which Nature turns, it being from the two Principles of Heat and Moisture, that all Action is given both to Vegetables and Animals, animated by the Heat of the Sun, and a Kind of Spirit, or Salt, which is latent and undiscovered in the Bowels of the Earth, and in the Blood of all Animals, Fish, Fowl, &c.

ON Plants, in particular, it is evident that this Spirit, or Salt, (call it which you will,) can have no Effect, unless it be dissolved by Water, being, as it were, fettered to the Earth, and incapable of doing any Thing necessary to any new Productions, but when dissolved by Water, and mingled with the Parts of the Earth; and thus animated, communicates itself to the Roots to nourish them; and, by a due Conjunction of Heat, digests that Nourishment, and turns into the Substance of Plants themselves.

THAT, as to the Animal System, it is the All-in-all by which Life itself (next to the Spiramina we every Day and every Moment breathe) is preserved, being the Vehicle by which all Nourishment is carried to the respective Offices of the Body, and without which there would soon be an Annihilation and Stoppage of them; and, sure it is, there is nothing, neither in the Vegetable nor Animal Kingdom, that is or can be transacted without it.

HOMER seems to have this in View in that charming, as well as useful Description he gives of the celebrated Gardens of *Alcinous*; where, after he had water'd the Plantations of his renowned Hero, and embellished them with Fountains, Cascades, &c. he distributes the Remainder to his Subjects in the lower Part of the Town by subterraneous Aqueducts and Pipes, as translated by one of our most excellent Bards.

*Two plenteous Fountains the whole Prospect crown'd,
This through the Garden leads its Streams around,
Visits each Plant, and waters all the Ground :
Whilst that in Pipes beneath the Palace flows,
And thence a Current on the Town bestows :
To various Use the various Streams they bring ;
The People one, and one supplies the King.*

Hom. Odif. 7.

SOME of the next Works of the Ancients of this Kind, that we have an Account of, were those of *Solomon*, who, as *Josephus*, in his *Jewish Antiquities*, Cap. viii. p. 204. tells us, had delightful Water-Works, and enriched Gardens at *Ittan*, about some eight Leagues Distance from *Jerusalem*, whether he usually and willingly retired

retired himself for his Pleasure, using all Things with admirable Providence and Promptitude, agreeable to the Account which he himself gives, of his beautiful Vineyards, Gardens, Orchards, and Pools of Water, mentioned in that admirable Treatise of *Ecclesiastes*, or the *Preacher*, Chap. viii. 4 & 5.

THE remarkable Cisterns at *Roselayn*, some few Miles distant from the antient City of *Tyre*, were, by common Tradition, suppos'd to be the Works of that Royal and Most-wise Prince, as a Part of Recompence to *Hiram*, for those Supplies of Materials sent by him towards building the Temple, tho' others ascribe it to a much later Date, and that they could not be built till since *Alexander's* Time, being carried over an *Isthmus*, or Neck of Land, that was raised by that Puissant Monarch during the Time he besieged that City, whereby he join'd it to the Continent.

HOWEVER it be, there are (as Mr. *Maundrell*, in his *Journey from Aleppo to Jerusalem*, gives an Account) at this Day three Cisterns, or Reservoirs, which not only drive the four Mills that stand between that Fountain and the Sea, but also supply that ancient and celebrated City with Water, for all Kinds of Uses : One large Cistern of twenty-two Yards Diameter, made of no other Materials than Gravel and small Pebles, but consolidated with a strong tenacious Cement, so that it appears to be one entire Vessel of Rock, elevated nine or ten Yards above the Ground ; which could be no small Expence, but a Demonstration that those primitive Genius's esteemed Works of this Kind worthy of their greatest Labour, Care, Attention, and Expence.

ONE of the other Cisterns was of twenty Yards Diameter, and the other of twelve Yards ; which being joined together, have for a long Tract of Time supplied one of the antientest, as well as largest Cities of the World with Water.

THE next Water-Works we have an Account of, were those stupendiously admirable ones of *Semiramis*, who, when she built or enlarged the Walls of *Babylon*, turned the River *Euphrates*, as some say, into a Basin of forty Miles Square, whilst she perfected that great Work, and till such Time as a new Canal was formed for the Reception of the River, with the several Trenches through which it was convey'd. What could be the Reason why such a Basin, as is before mentioned, should be made, is not easy to conceive, since the new Canal might have been dug, during the Continuance of the old one, (as we now do our new Rivers, during the Continuance of those that were running before ;) and besides, even forty Miles Square could not long contain so great a River as that

4. *An Introduction to a General System*

which the *Euphrates* was, (were it possible such a Basin could be dug :) And, indeed, the whole would seem fabulous did not so many great and learned Men affirm it ; and that a very ingenious Author, on a Survey of those numerous Armies and Subjects that were always at her Command, and to shew the Prowess of so great a Princess, seems to assent to it, I mean the ingenious Author of the *Spectators*. VOL. VI. N^o. 415.

THE stupendious Aqueducts, and other Contrivances for Water in *Rome*, and other Parts of *Italy* and *France*, who copied after them, are eminent Instances, that those great and wise People placed them amongst their greatest Improvements of Architecture, (whether Civil or Military,) as they were indeed more useful, and contributed more to the Safety and Necessity of their publick Communities than any of their other Works could ; and their Aqueducts and Cloacas were such, (being raised on prodigious high Arches,) that *Pliny* took occasion to say, That the City of *Rome* was suspended in the Air.

Montfaucon, in his *Antiquities of Rome*, VOL. IV. Page 165. says of them, “ That they were one of the Wonders of the World ;
“ and that there were many of them which brought Water thirty or forty, and some sixty Miles Distance from that City : That there
“ are considerable Remains of them in the Neighbourhood of *Rome*
“ to this Day, being long Rows of Arches, over which the Water was
“ carried, (as it is now between *Marli* and *Versailles*,) for many
“ Miles together : Those Arches (says he) are sometimes high,
“ and sometimes low, as the Inequality of the Ground required :
“ That they were built of Brick well cemented together : And
“ that in all Places where the Ground was too high and Rocky,
“ they bored through them, that the Course of the Water might
“ not be interrupted. And what was very remarkable, those
“ Aqueducts which might have been carried strait, were made turning and winding, not unlike the *Ziczac*’s now in use in Gardens ;
“ which (according to the celebrated *Fabretti*, with whom later
“ Experience also agrees) was for the taking Advantage of high
“ Ground ; for had they been carried through Ground that was
“ lower, the Arches must have been of a much greater Height
“ than they were, and consequently the Expence would have been
“ (tho’ not much perhaps consulted by those generous and great
“ People) much larger.”

THAT the Stoppage of the Water, which was occasioned thereby, was for its Purification, or that the Impetuosity of it was thereby restrained, (according to *Flaminius Vacca*,) is a Supposition that
seems

seems not to carry with it the Weight which *Montfaucon* supposes, since the more Obstructions Water meets with, the more turbid and less pure it is.

THE aforementioned Author *Fabretti*, who appears to reason very much like an Architect, and whose Drawings *Monf. Montfaucon* has exhibited, gives both the Images, Sections, and Account of the *Aqua Maria, Claudia, Julia, Tepula, Marcia*, and *Neroianana*, which was brought in several Canals: That which conducted the *Aqua Claudia* was built of square Stone, and that of *Neroianana* of Brick, and, according to *Fabretti*, was seventy two Roman Foot high: The Canal of the *Aqua Appia* was not made like other Canals, but was disposed within into Steps as it were, so that it grew narrower and narrower towards the Bottom.

WHAT would be remarkably prodigious, would be the great Height of those Aqueducts, if we were not at the same Time told, that there were three or four several Canals, through which those several Sorts of Water was convey'd from different Springs of different Heights, and for different Uses, and which those great Architects reduced into one Pile of Work, not only as it was commodious for their then Undertakings, but to exemplify the Greatness of that State, which did not (as may be seen in almost all their publick Works) consult Expence so much as Grandeur, since, as *Montfaucon* observes, it is so astonishing that few (it may be added, except the late King *Lewis XIV. of France*) would have undertaken so stupenduous a Piece of Work from that, even to this Day.

To proceed, (with that laborious Author,) the admired Aqueduct of *Metz* was a Work worthy of the *Roman* Grandeur and Magnificence, being built over the *Moselle*, a great River; and at that Place very broad, where those Waters were gathered into a Conservatory, and from thence conveyed thro' several Canals, made of square Stone, and so spacious, that a Man might almost walk upright within them. Another of the Aqueducts our celebrated Author makes mention of, is that of *Segovia* in *Spain*, which he tells us may be reckoned amongst the most excellent Monuments that Antiquity has transmitted to us; and that there remains at this Day an hundred and fifty nine Arches, all built with large square Stone, without any Cement; and that they were one above another in two Rows, the Heights of which, taking in the whole Structure, is an hundred and two Foot; and that the Aqueduct is carried thro' the City to the highest Ground.

6 *An Introduction to a General System*

EVEN the Cloaca, or common Sewers of *Rome* before mentioned, the Work (as the Reverend Mr. *Echard*, in his *Roman History*, tells us) of the first and great *Tarquin* himself, were also celebrated amongst the Wonders of that Mistress of the World; and so large, that People might row through them with Boats, (as some few Years since we have heard of those of *Cremona*;) and the Breadth and Height of some of them was great enough, for a Waggon loaded with Hay to pass through them; and for the cleansing of which, there was such an incredible Quantity of Water brought to *Rome*, that it was impossible any Stoppage or Stench should well happen.

To conclude this Account of *Rome*, the *Claudian* Aqueduct, (as Mr. *Addison* observes, VOL. II. Page 131. of his Works,) was thirty eight Miles in Length, through which the Water was brought to *Rome*, by the Advantage only of a high Source, and the low Situation of that City, and that the Architect has allowed five Foot in a Mile, for the Descent or Current of the Water that passes through it; which I mention, because it is an Observation that *Mont-faucon*, nor no other Author of the Accounts of *Rome*, (that I have seen,) take notice of, and may be a Demonstration of the curious Enquiry of that deservedly ingenious Gentleman, who by his Works has been so great an Honour to his Country, and one amongst the many Arguments that might be produc'd, that his Writings can never be justly too much admired.

To enumerate, and put down at large, all the Works of this kind, which have heretofore been done in *France*, or those lately done in *Muscovy*, would be a just Volume itself. That noble Canal, which according to some Histories I have seen of *France*, was done, (as I remember,) by *Henry IV.* somewhere about *Tholoun*, is a Work worthy of the Magnificence of one of the greatest Potentates on Earth.

THE Account of the Water-Works of *Versailles*, would, (with the Machine of *Marli*, the Length and Difficulty of the Passage of the Water from thence to *Versailles*, the Reservoirs, Canals, &c.) be a perfect History itself, having without doubt cost such immense Sums of Money, as few Princes in the World would again lay out, and therefore beyond the Example and Imitation of inferior Subjects, for whom this Work is chiefly calculated; and I have been very credibly inform'd, that a Nobleman of the first Rank of this Kingdom in particular, (I mean that great Duke of *Bolton*, the Grandfather of his present Grace, the remarkable *Brutus* of his Age, that like that first *Roman* Noble, feign'd himself mad, (as his Patent sets forth,) to save

save his Country,) fold as much Lead towards the Fountains and Basins, as brought him in at least 250000 *l.* Sterling, clear of all Expences.

THOSE Pieces of Water (as they are by the *French*, by Way of Irony term'd) are by the Prints, as well as by the Accounts Travellers bring, all noble and large, (though the Water itself be not very clear;) and the Numbers of them are such, that there is not, in the Compass I propose to myself in this short History, Room to set them down.

To omit then the Fountains or Basins of *Saturn*, *Flora*, *Bacchus*, *Ceres*, and *Latona*, with the Pyramid in the Parterre on the North-Corner of the Castle, and many others of less Account, there are five or six Pieces that claim the Attention of the most Curious.

AND the first is the grand Obelisque or Mountain of Water, which has one very great Gerb compos'd of two hundred and thirty one Jets of Water, and which rises fifty Foot high. The Obelisque, which is at least four or five Foot Diameter at the Bottom, and about one or two at Top, may be justly accounted one of the greatest Pieces of Art and Expence (when we consider that innumerable Quantity of smaller Pipes that join to compose it) which is to be seen in that or any other Country.

The Basin of *Apollo* is also sixty Toises long, and forty five wide. The Groupe of *Apollo*, with the Tritons, Sea-Horses, and other Genii, with that grand Gerb which rises seventy Toises high in the Center of the Basin, and fronting the Middle of the great Canal, the Design of the famous *Le Brun*, may be justly accounted amongst the greatest Works of that magnificent Place.

THE Basin of *Neptune*, another Design of that great Master's, is a most beautiful Piece of Water, adorn'd as it is with above fifty large Jets, that play twenty or thirty Yards high each, and adorn'd with several Napes, and twenty two Vessels of fine Metal. This Basin, according to the *French* Measure, is one hundred Toises long, and sixty wide; and being situate at the lower End of the fine Alley of Water that comes through the Wood-Work, from the North-Corner of the Castle, makes (as appears by all Accounts) one of the noblest Figures of any of the Water-Works about the Gardens.

I SHALL but just mention the grand Theatre, and triumphant Arch of Water, the Designs of Mr. *Le Nautre* and *Le Brun*, adorn'd by almost an innumerable Company of lesser Fountains, Cascades, Jets, Buffets, Groupes, and other Embellishments; which when they are in order, and play, are amongst the most surprizing Works that Art ever yet form'd.

BUT

BUT before I quit this Account of the Water-Works of *Versailles*, I must not omit that noble Body of Water, call'd the *Isle Royal*, placed in one of the Quarters of Wood in the Gardens there. It is about an hundred and thirty Toises long, and sixty wide, as the Prints, sometime since brought from *France*, intimate; and what makes it have the greater Effect to the Eye, is, that it is environ'd with Portico's and Hedges cut into Arch-Works, shaded with a Row of Trees that accompany it; and at that End of it, which is next the Castle, there is also another Piece, through which the Dauphin's Walk (as they call it) passes, which Piece is adorned with the Statues of *Julia Mæsa*, *Venus*, *Jupiter Stator*, and *Julia Damna*, with Vasa's of white Marble by *le Fevre* and *Legeret*; and the great Piece is set at the further End, with two Collofies of *Hercules* and *Flora*, from the *Farnese* Collection, being Copies from *Rome*, by *Cornu* and *Raon*.

THE Canal is a thousand Toises long, and near forty wide; a Part of which, at the farther End, is an Estang, or Basin, of an hundred and eighty Toises long, and an hundred Toises wide, in which there is an old Ship fix'd; and the Cross or Transverse Canal, which makes it appear like a Cross, is five hundred Toises long, and between thirty or forty Toises wide.

THE Fountain *de l'Encelade* is one of the chief Pieces of Water that is contain'd within the Wood-Works. The Figure the Water plays from, is a large Giant, four Times as big as the Life, out of which proceeds a large Gerb of Water, that plays seventy eight Foot high, encompass'd with a vast Number of Bouillons, that spout out of the Hands, Feet, &c. the Design of the famous *le Brun*, and the Jet made from the Model of Monsieur *Esparade* of *Marli*. The whole appears to be the most beautiful of any enclos'd Piece of Water in the whole Gardens of *Versailles*. To this may be added, the Bains *de Apollo*, a Piece of Groupe-Work in white Marble, wherein is placed the Goddess *Thesis*, accompanied by six Nymphs that are Servitors to her: On each Side of this large Groupe are two smaller ones; in the Middle of which are the Coursers of *Apollo*, attended by *Tritons*. The Embellishments of this expensive Structure are many of them of Gold, and the whole being the Design and Execution of four of the greatest Masters of *France*, *Gerardon*, *Regnaudin*, *Guerin*, and *Marsi*, are in the Number of the most curious Pieces of Art which that Palace produces.

THE Water-Works of *Marli*, *Meudon*, and several other Places in *France*, are also very admirable, the contracted Cuts whereof I intended to have made a Part of this Work, but that I find them already done

done by Mr. *Bowles*, Printfeller in *St. Paul's Church-Yard*, where all those of *Versailles* may be had in Sets, and will not be improper Appendixes, for all Gentlemen who approve of it, to be put to the later End of this Treatise.

To proceed, we are no Way behind hand in *England*, though not in the great Beauty, yet in the Advantages that Water has procured to Trade, as well as for the Convenience of watering Cities, Towns, large Tracts of Meadow-Land, Upground, &c. by the raising of Damns, Wares, and the like; and by the cleansing of navigable Rivers and Water-Courses.

REMARKABLE enough, being that expensive, but yet useful Work that supplies *Plymouth* with Water; "A Work (as the learned Editor of *Camden* observes) which was done by the Contrivance, and at the proper Cost and Charge of that great Admiral and Discoverer of unknown Countries, (at least by a Relation of his,) of the antient and noble Family of the *Cavendishes*, now Dukes of *Devonshire*, who brought to that Town a large Stream of Water from a great Distance, through many Windings and Turnings, driving many Mills, and serving for other necessary Uses and Conveniences of the Inhabitants."

THE New River, that supplies the greatest Part of *London* and *Westminster* with Water, arising from the two Springs *Amwel* and *Chadwell*, near *Ware* in *Hertfordshire*, appears to be a Work worthy of the vast Charge and exquisite Skill of Sir *Hugh Middleton*, who in five Years Time, viz. from the Year 1608. to the Year 1613. conducted it through Fields and Meadows in a turning and winding Course for above sixty Miles, before it reaches this rich and opulent City; in the Course of which the Channel is necessarily carried in some Places twenty Foot deep, and in other Places twenty Foot higher than the natural Level of the Ground, in Aqueducts or Troughs of Wood above Ground; and has over it in that Course eight hundred Bridges, some made of Wood, some of Stone, and others of Brick; the River feeding and supplying, by the Help of the Mill at *Islington*, all the lower Rooms, at least in the highest Part, and the upper Rooms in the lowest Part of that populous City. And, though the Water may not be so pure as if it were convey'd in Arches of Brick or Stone, as that of *Rome* was, yet by its being vented into a large deep Reservoir, it is considerably settled and refined; and is a Work that few Cities of the World can boast of, and fewer yet excel: Nor would it be much to my Purpose, but would take up too much Room in the Compass I propose to allow myself in this Introduction, to take notice of all the other Methods whereby *London*

and its powerful Neighbour *Westminster*, is supplied with Water; nor of those Inventions that are every Day on foot for supplying of two Cities growing more populous and populous, and which, we may expect will, in a few Years, much excel the largest Cities of the World; some Account of which may be expected in the following Sheets, as what will help to give the truest Idea of this Mistress and Metropolis of *Great Britain*.

To go on with our History: The great Labour and Expence that has been bestowed in the draining or drawing off the superfluous Water in the Fens in *Cambridge* and *Lincolnshire*, Isle of *Ely*, and other Places, would swell this Introduction beyond its proposed Limits, as would also the raising of Rivers and Carriages for the Overflowing of Meadow and Uplands in the several Counties of *Southampton*, *Wilts*, and *Dorset*, especially about *Sarum*, *Dunton*, *Winton*, and other Places. But I must beg leave to assume to myself the Credit of an Undertaking of this Kind, performed some Years since for the Earl of *Coningsby*, at *Hampton-Court* in *Herefordshire*; which, though not brought above two Miles, may (considering the Difficulties that attended this useful, but expensive Work) be reckoned amongst some of the greatest Undertakings that were ever attempted in this or any other Country by a private Purse; yet, though the Cost of it has been little less than 1200 *l.* it has laid a Foundation for the Watering of two or three hundred Acres of Land, that is, and may be very well improved from five or six Shillings, to twenty or thirty Shillings an Acre at least.

THIS Work, begun and finished in eight or ten Months, was conducted by many Windings and Turnings through high and almost impenetrable Rocks, some of at least ten or fifteen Yards perpendicular, and over other Variety of Earth, Clay, &c. in a Drain or Carriage about five Yards wide; which emptying itself on some high Lands or Eminencies that lie above that antient Seat, waters all the Land thereabouts, and causes an uncommon early Verdure, and Profit to the Possessor, though much higher than the Top of the House itself: Which I mention the rather in this Place, that it may incite other Noblemen and Gentlemen to the Prosecution of the same, wherever there is an Opportunity, the Recompence being at least 20 *l. per Cent.* for their Money, clear of all Charges.

THE Carriage that plays the Engine at *Blenheim*, and other Works of that Kind, done in several Places of *England*, have fallen to my Lot, with, I hope, the desired Success.

IT must be confess'd that we are not yet arrived to that Grandeur in our Garden Water-Works in *England*, as they are in *France*

of Hydrostaticks and Hydraulicks.

11

or *Italy*, though the Advantages we have by Nature are as great or greater than any that are to be met with in other Countries. The *Villa de Medicis*, with its Water-Works, the Cascade of the *Teverone*, with the famous Falls of the *Frescati*, to omit many others, which are accounted by Travellers amongst the greatest Works that either Nature or Art are capable of furnishing the World with; and, whoever reads the charming Description that Mr. *Addison* gives of those Works and the adjacent Country, will observe it to be a Subject, wherein not only Travellers and Poets, but the most skilful Painters in *Italy* and *Rome*, have employ'd themselves to great Advantage.

HORACE, (as Mr. *Addison* has it,) had his Eye upon it in the agreeable Touches he gives of those beautiful Landships,

*Me nec tam patiens Lacedæmon,
Nec tam Larissæ percussit campus opimæ,
Quam domus Albania resonantis,
Et pæceps Anio & Tiburni lacus & uda
Molibus Pomaria Rivis.*

HOR. lib. Od. vii. v. 10.

In *English* thus,

*Not fair Larissa's fruitful Shore,
Nor Lacedemon charms me more,
Than high Abania's airy Walls
Resounding with her Water-Falls;
And Tivoli's delightful Shades,
And Anio rowling in Cascades,
That through the flowry Meadow gilds,
And all the beauteous Scene divides.*

ADDISON.

AND when they are made to appear by many Breaks and interrupted Scenes, made up of an infinite Number of an Inequalities that naturally arise from the agreeable Mixture of Hills, Groves, and Valleys, which there appear; and when its Stream is broken by such a Multitude of Cascades, that so often shift themselves from one Channel to another, and after a very rapid and noisy Course from Hill to Hill, at last to fall into the antient and celebrated *Tyber*, is a Description that from so uncommon a Pen, carries with it something that is stupendiously natural and great.

And it is agreeable to this, says our worthy Author, that we are to understand *Silius Italicus's* Description, to give it its proper Beauty.

*Here the loud Anio's boisterous Clamours cease,
That with submissive Murmurs glide in Peace
To his old Sire the Tyber. -----*

ADDISON'S Works, Vol. ii. p. 129.

OF little less Beauty (but perhaps great Use and Account) to those celebrated Landscips, though not in the Precipitancy of their Cascade, yet in their natural Turnings and Meanders, are many of our Rivers in *England*, which when lying beneath (as many of them do) fruitful Hills, many of them cloathed with noble Amphitheatres and Coverings of Wood, claim a Share, if not the Precedence, of any Views yet mentioned.

FOR whoever yet beheld the River *Wye*, (on the Banks whereof has been the Residence of some of our antient Bards,) passing by many Windings and Turnings from *Ross* by *Hom-Lacy*, the Seat of the noble Family of the *Scudamores*, to *Hereford*, &c. but must be extremely surpriz'd at the Beauty of those Voluta's it appears to make, adorned as it is with such prodigious lofty and natural Amphitheatres of Beech and other Wood, reaching in Appearance to the Skies, in many Places a Quarter of a Mile high, and generally full of Springs. To this pleasant Scene may be added that beautiful Hill facing *Hampton-Court* aforementioned, in that County, under which runs the River *Lugg*, forming a natural Semicircle, or Half-Moon, which by the Height of the Wood, the Agreeableness of the Verdure, may, I humbly conceive, be accounted amongst the best determinate Prospects any where to be seen.

NOR need we in all Probability give Place to *Italy* or *France* itself, in some artificial Cascades and beautiful Falls of Water in *England*; those of Mr. *Blaithwaites* at *Durham* near the *Bath*, of Mr. *Ernly's* at *Whetham*, those of *Chatworth*, belonging to the great and noble Family of the *Cavendishes*, are worthy of Account: But what is more stupendious than them all, the Drawings of which I am endeavouring to procure, are those fine Falls of Water belonging to Mr. *Aisleby* in the North, with those of *Bolton*, &c. To proceed in Nature;

THE River *Avon* in *Hampshire*, and adjoining to the new Forest, (remarkable for that eminent Danger from which *Titus* is said to have rescued his Father *Vespasian*, when closed besieg'd by the *Britains*,) begins at *Charford-Farm*, (as *Camden* tells us, so called from *Cerdick*,

dick, a valiant *Saxon*, that also gave the *Britains* so great a Defeat on the Banks of that River,) passes through many fine Meadows by *Folden* or *Forden* Bridge to *Ringwood*, &c. till it joins the *Stour* near *Christchurch*, and has the Woods of the new Forest rising like an Amphitheatre on the South, which gives such an agreeable Prospect to those Seats that are situated on the North-Side, especially *Breamore*, one of the Seats belonging to the Lords of *Brooke*, the Place from whence these Memoirs are dated; from which, through many green and delightful Meadows, and in View of Mountains, and woody Landships, you see it take its Course till it falls into the Sea at *Christchurch*, and is, as it were, lost in the Surges of that voluminous and extensive Ocean.

THE *Avon*, another River of the same Name at *Warwick*, merits a Place in this short Account of Rivers, as it passes by the Town and other rising Grounds that lie contiguous to an antient and noble Castle, which is so great a Strength and Ornament to that delightful Town.

THIS Place, (if it be the same that *Camden* speaks of,) is, in his Words, the Seat of Pleasure it self. There, or near to it, (perhaps that which is now the *Lady Bowyers*,) and which has this fine River in View, is (says he) a shady Grove and chrystal Springs, mossy Caves, Meadows, Ever-greens, soft and murmuring Falls of Water under the Rocks; and to crown all, Solitude and Quiet, the greatest Darling of the Muses, the Place where *Fame* tells us, (says that laborious Author,) the celebrated *Guy* of *Warwick*, after he had finish'd his martial Atchievements, built a Chapel, led a Hermit's Life, and was at last buried.

THE River *Trent* leading from *Nottingham* to *Newark*, the *Severn* from *Gloucester* to *Worcester*, and so on to *Shrewsbury*, are both of them lasting Monuments of the Nobleness of our Rivers, and that they equal, if not excel, the so-much-talked-of *Tyber* and the *Sein*, as may the River *Lodon* and the *Thames* that of the *Danube* and *Mozelle*, if not in the Extent, yet in the Limpidity and Clearness of their Streams, so beautifully described by one of our *English* Bards.

*Though deep, yet clear, though gentle, yet not dull,
Strong without Rage, without o'er-flowing full.*

DURHAM'S *Coopers-Hill*.

To finish this historical Account of Water-Works, to which the Delightfulness of the Subject has insensibly led me, let any one but take a View of those that are at *Chatworth*, *Bowden*, at Mr. *Brathwaite's*,

14 *An Introduction to a General System*

waites near the *Bath*, just mentioned, and other Places, to which if you would add that which is newer, (and in some Respects nobler and greater,) those of the late Duke of *Kingston* at *Thoresby* in *Nottinghamshire*, and of the new Lake at *Blenheim*, the Work of that illustrious and Right Noble Lady, the present Dutches Dowager of *Marlborough*, will see to what a Pitch practical Hydrostacy is arriving to in *England*, and how we are like to emulate most of our Neighbours in these beautiful Embellishments.

AND to finish this; I conceive that the Canal and Cascade at *Busby-Park*, the Draught of which I have hereto adjoin'd, the sole Contrivance (I had almost said manual Operation) of that truly ingenious Nobleman, the then *Mæcenas* and Encourager of all Arts and Sciences, the late Earl of *Hallifax*, is, without doubt, one of the best Works of that Kind in *England*, and perhaps as good as any else where. And thus much I thought proper to say in Commendation of my own Country, (compar'd to others,) and as much as in me lies, to create such a due Emulation amongst my Countrymen, as may incite them to the Improvement of this natural and useful Beauty, which when added to the Fineness of our Turf, and the Nobleness of our Timber, may (as we are in many other Cases) be the Envy of our Enemies, and the Delight of our Friends.

C H A P. II.

Of the Origin and Rise of Springs, and of the Opinion of those who ascribe them to Air, Vapours, Dews, Rain, Snow, &c.

THE Original and Rise of Springs, like most other Things whose Causes lie conceal'd, have met with a Multiplicity of confus'd and unnecessary Opinions, by which Truth has been either strangely disguis'd or deliver'd in dubious and ænigmatical Terms, such as has puzzled, rather than instructed those whose Genius's have led them to the Study of this Part of Meteorology. On this Account it is that I have in this Essay endeavoured, what I can, to set this Matter in the clearest and most perspicuous Light, and to fix the tedious and uncertain Accounts we have of Springs on some more rational Basis, by giving Reasons why those Opinions which were delivered in the antient, as well as some modern Philosophy, ought to be rejected.

FOR

FOR that of *Aristotle* and his Followers, who judge it to be from Air, included in the Caverns and Vaults of the Earth, and there by the constringent Cold of those Receptacles condensed into Water, is very unlikely, if not altogether impossible; for admitting there be (as a learned Physician in a Manuscript I have seen on this Head has it) such a Mutation of Elements, (which has often been disproved,) if we consider the mathematical Difference which there is between the Bulk and Proportion of the two Bodies of Air and Water, how vast must those Caves be, which in its State of Rarefaction can contribute or contrive Air enough for the perennial Streams of a large Fountain? And though we should allow them the same alternate and successive Supplies which they impart to Water, yet we are to conceive, that they must be detain'd for some Time in those Caverns before they are condens'd, and so not always *in Transitu*, as Water is.

BESIDES all which, (with *Marriotte*,) it is a dubious Point, even to be denied, that there are such Caverns or hollow Places in the Ground capable of such Performances, the Places from whence Springs proceed being generally composed of small, gravelly, sandy, or small rocky Ground, those Caves having never been actually, that I know of, discover'd; though by the issuing out of Springs from the Sides of Hills, they ought to be some where near at Hand, and therefore in all Probability have no Existence, but in the Minds of their chimerical Inventors.

BESIDES this Opinion of the Peripateticks, there are several others maintain'd by Philosophers of later Ages, as that of *Aquinos*, who held their Original to be from the Stars and celestial Influences. *Scaliger* thinks them to be from the Earth's pressing of the Waters; and *Faber* from the Attraction of all Waters by the North Pole, by which being carried to the Centre of the Earth, they are thence, being first impregnated by the Virtues of the universal Spirit, dispers'd into the several Channels of the Earth, all which hypochondrical Conceits dying with their Authors, have been but little noted: Those of *Senectus Bartholinus*, and some later Writers, as *Plott*, *Hook*, &c. having much more Weight with them, there being nothing more consentaneous to Reason, whether physical or mechanical, and the Analogy that naturally subsists between the Macrocosm and Microcosm, (in both which the Laws of Elasticity take place,) than the Circulation and Ascension of Waters in the Bowels, and on the Surface of the Earth, as the Blood does in the Body, or rather, as the Sap does in a Tree.

FOR if we take a Survey, and acknowledge any thing of that Nature which is in Animals and Vegetables, it will be easily demonstrated, that Water serves the Earth for the same Purposes, as the Blood does the Body, or the Sap the Trunk and Boughs of a Tree, and is elevated by the same Means, namely, for the Irrigation of those Parts of it which are dry, and to reduce it to such a Consistence as to be fit for the Impressions of the universal Spirit, even as it supplies the Nerves of the Body, or the Pores of the Tree, with those animal Spirits or rarify'd Juices which circulate in the Body, or ascend the Trunk of a Tree; it being by this constant Supply of Spirits and rarified Juices, that both a Production of new Matter, as well as a Supply to what was before decay'd; and from the perpetual Ascension or Circulation of the liquid Matter therein contain'd, that the Motion, on which depends all the Actions of Vitality in both, is continued. And I must confess I have often wonder'd that so many Philosophers, (and some of them of a new Date too,) when they are so curious in their Enquiries into other Parts of Nature, and suppose them to consist of such an innumerable Chain of Causes, should resolve this great Point into the dull and lazy Laws of Gravitation and natural Propensity, when its first Source, Motion, and Ascent, is so easily accounted for by the new establish'd and now so-well-understood Laws of Pulsion, as having its first Source from the Sea, and being arriv'd through all the permeable Parts and subterraneous Channels of the Earth, in a due Circulation and Ascent, (as it appears in all percolated and ascending Liquors,) either in a swifter or slower Current, (according to the Largeness of the Passages in which it runs,) through those Veins, Channels, and Ducts of the Earth, till it breaks out of the Sides of the Hills, and traverses its Way, even to its Return into the Sea again; from whence, according to the Opinions of some of the best Philosophers, both antient and modern, it had its first Rise.

BUT to proceed to a strict Examination of some of those erroneous Opinions that have long subsisted in the hidden Cause of Springs, there are * (as *Marriotte* in his *Hydrostaticks*, Page 15. of the *English* Edition, by the Learned *Desaguliers*,) that give another Reason for their Origin and Rise, attributing it to Vapours, and not Air,) which proceeding from the innermost Parts of the Earth, meet with

* Of this Opinion also is *Rohault*, one of the Chief amongst the Cartesian Philosophers, who (Cap. x. Page 41. of *Dr. Clarke's Edition*,) says, that they are from Water dissolv'd into Vapour by subterraneous Heat, which by its own fluid Nature is carried to the Tops of the highest Mountains, &c.

with Rocks which are on the Tops of Mountains in the Form of Vaults, do then become Water, as in a Still, and then run out at the Foot, or the Declivity of those Mountains, in the Manner we see them; but this Supposition (says our ingenuous Author) can hardly be maintained. For if A, B, C, Fig. 1. Plate 1. be a Vault in the Mountain D, E, F, it is evident, that if the Vapours should become Water in the Concave of the Surface A, B, C, that Water would fall in a perpendicular Manner towards H, G, I, and not towards L, or M, and consequently never make a Spring. Besides, as it is elsewhere observed, it is denied that there are Hollows enough, if any at all, of a Capacity large enough to make such Springs; and it can't be made appear (says *Marriotte*) that there are any such.

If it be said that there is Earth on the Side of, and beneath A, B, C, it will be answered, that the Vapours will gush out at the Sides towards A and C, and that very little will become Water; and because it appears that there is almost always Clay where there are Springs, it is very likely that those supposed distilled Waters can't pass through, and consequently that Springs can't be produced, by that Means. And as to what some Authors tell, that Springs have ceased running, for having given Vent to great subterraneous Cavities, from whence there proceeded great Quantities of Vapours which became Water, *Marriotte* suspects to be Stories. But it is not denied that there may be such Dispositions in the Tops of Mountains, and chiefly such as are covered with Snow, (such as the curious *Ray*, in his topographical Observations, Page 103.) mentions to be at the Foot of the *Alps*, where the Springs flow very sparingly in the Winter; but in the Summer, and upon the supposed Dissolution of those Snows, in a luxurious Manner. But this is rarely to be met with in *England*, and can't be drawn into Consequence as to other Springs.

THE ingenious Dr. *Halley*, in his Account of Springs, published in the Transactions of the Royal Society for *January* and *February*. 1692. (and from him Monsieur *La Clerc*,) affirms, that Springs owe their Original to that great Quantity of Vapours which are drawn out of the Ocean by the Heat of the Sun; and after that, when the Sun departs the Horizon, descend again in the same great Quantities on the Tops of high Hills, Mountains, and other upland Grounds, (especially amongst the Tropicks, where it put his astronomical Instruments into a great Disorder; and particularly, that his Paper was so very wet, that in a short Time it would not hold Ink; adding, that those Observations were made not only in *Europe*, but also in the Island of *St. Hellens*. And asserts farther from thence, the Manner how Springs may come to break out on the Tops or Sides of high

D

Hills,

Hills, rather than below;) and that those Vapours are dispersed here and there by the Winds, and so lodge themselves rather there than on low Situations, sinking down a little Way into proper Receptacles and Reservoirs, where gathering together, they break out in the Manner we see them.

THE general Computation which that learned Author makes, as they are abridged by a very ingenious Hand, take as follows, extracted as it is from the *Philosophical Transactions*, N^o. 189, 192. where from two Experiments he has endeavoured to make appear, that the Sun and Wind can't raise less than $\frac{1}{10}$ of an Inch Cubick of Water in a Day; each square Foot half a Wine Pint, every 4 Foot Square a Gallon, a Mile Square 6914 Tuns, a Square Degree, suppose it be 60 *English* Miles, 33 Millions of Tuns.

AND if the *Mediterranean* be estimated at 40 Degrees long, and 4 Degrees broad, it will be 160 Degrees Square of the Sea, and consequently will lose in Vapours 5280 Millions of Tuns in a Day.

THE *Mediterranean* receives these considerable Rivers, (*viz.*) the *Ebro*, *Rhone*, *Tyber*, *Po*, *Danube*, *Neister*, *Neiper*, *Don*, and the *Nile*; and we will suppose each of these 9 Rivers to bring down ten Times as much Water as the *Thames*, to wit, from a Calculation there made of 1827 Millions of Tuns in a Day, will be brought into the *Mediterranean* by the Rivers running into it, which is little more than what is proved to be raised in Vapours from the Sea in that Time, one Part falling back again into the *Mediterranean* in Rains and Dews, and the remaining Part is supplied by the Current constantly setting into the Straits at *Gibraltar*. Hence likewise appears the Reason of the *Caspian* Sea's never overflowing at all, tho' it receives so many large Rivers, yet sends forth none, as much being carried off in Vapours as the Rivers supply.

Now if an Atom of Water be expanded by Heat into a Bubble, ten Times bigger than it was in its natural State, such an Atom would be specifically lighter than Air, and rise continually, till the Warmth declining, and the Air growing cooler, and withal specifically lighter, the Vapours consequently shall stop, or descend at a certain Region of the Air. Next consider the Earth's Surface, as interspersed with high Ridges of Mountains, to which, when the Vapours are carried by the Winds, they are compelled by the Stream of Air to mount up with it to the Tops of those Mountains, where being precipitated by the Cold, it gleets down the Crannies of those Stones, and uniting, forms single Springs; the Union of several of which forms Rivulets, many of which joining together form Streams, such as the *Danube*, &c. which latter, one would hardly think could be

be composed of Vapours, were it not considered at the same Time what vast Tracts of Land that River drains; in Proportion to which, and for the aforesaid Reason, we find Rivers great or small. From this Hypothesis likewise appears the final Cause of Hills, which serve for Alembicks to distil Waters for the Use of Man and Beast.

BUT for a more particular Account how this great Work of Nature is performed, and how those Vapours are raised from the Sea, the Explanation of the following Plate does more clearly demonstrate.

THESE Vapours then which are raised from the Sea, from P, to g, and F, may be thus accounted for. Let Fig. II. Plate 1. represent the Globe of the Earth, to P, Q, R, S, surrounded by the Air, as far as B, A, D, which being heavy in it self, and thereby capable of being compressed, grows continually finer from below at P, upwards through g, and F, to B, and consequently lighter, because its elastick Faculty dilates it more in Proportion, as the Pressure of the Air is diminished; and as it scatters the Particles of Air from each other, renders it lighter in an equally enlarged Space. And if we now suppose farther, that this same Air is heavier below at that Part of the Globe which lies between F and P, and lighter above between F and B, than the Water evaporated or mingled with Fire, so that about F, G, H, the said Air is of equal Gravity with it, it will follow from what has been just now mentioned, that the Vapours between F and P will ascend; that being raised to the Bounds of the Equilibrium F, G, H, they will float like Clouds at I, and I, G; and being equipoised, will neither rise nor fall; but when raised higher to B, I, or H, D, they will descend.

THIS demonstrates how Vapours are rais'd from the Sea from P, to g, by the Warmth of the Sun; as also how they are enabled to float in thin Air, as in different Stages and Degrees of Height as g, K, d, and F, I, G: And, moreover, why the said Vapours being rais'd higher up to Z by the Winds, or driven against one another by contrary Winds, and for other Reasons do descend in Rain, Snow, and the like.

BUT Dr. *Halley* subjoins another Manner to these, namely, that a floating Vapour or Cloud in E, being driven against the Mountain Q, N, R, by the Winds at E, ascends to the Top N, and there being got into a lighter Air, cannot be any longer sustained, but falls down in small Drops upon the Head of the Mountain, and from thence running down, fill the Cavities of the Mountains, (which contrary to the Opinion of *Mariotte*, and others, are supposed to be found there with Water, and so continually running down through the Orifice at M, produces the little Brooks m, e, F, or M, e, V;

which joining themselves with others of the same Nature, form a large River.

By this Way it appears then, (says my Author,) why the Waters are assembled in greater Quantities upon the Mountains, than below; for as much as their Tops from Q, R, to N, against the Winds which drive the Clouds m, E, K, d, &c. they serve for Barricadoes, or Cross-trees, and so do either force the Vapours to ascend into a lighter Air, or forcing them against those Tops, squeeze them together, whereby they become heavy, and fall down again.

Now these Vapours (say our Naturalists) are condens'd by the great Shadows which these Mountains produce, and which occasion a continual cold Air about them, even in the hottest Seasons, as is seen in the Extract of the History of *Bohemia*, *Act. Lips.* 1682. Page 244. And on some Places, even on the *Alps*, in *Italy* it self, where the Snow has been known to remain for sixteen Years together, the old being of brownish Colours, by which they were distinguished from later Snows, which were white and clear.

SUPPOSE then the Sun to be at O, Fig. II. of the following Plate, where the Mountains Q, N, R, casting its Shadow, as Q, E, X; there the Sun-Beams are hindered, either by Mountains lying about it, or because the Sun shines seldom upon that Side, from ever heating the Air to such a Degree, as is found in the next adjacent Air. It is plain then that the Air within the Shadow Q, E, X, will be a great deal colder than that which encompasses the Mountain out of the Shadow. And this is the Cause of the Condensation, and consequently the heavy Descent of these Vapours, now supposed to be turned into Water. And to shew how the Sea is dispos'd to emit such a Quantity of Vapours as are necessary for the above mentioned Purposes, the learned *Halley*, in his *Philosophical Transactions* for September and October 1688, has set down an Experiment made in a Vessel full of Water, 4 Inches deep, and 7 Inches $\frac{2}{10}$ in Diameter, where having warmed the Water to such a Degree as he supposed the Air might be in some of the hottest Months of the Year, by weighing, he found that there was almost a Quarter of an Ounce evaporated in about an Hour's Time, altho' there was little or no Reak or Smoke; neither did it upon the dipping in of the Finger appear to be hot: From which it may be calculated, that in 24 Hours Time, there would be 6 Ounces evaporated out of that small Superficies. The *Oxford* Society have carried this Experiment yet further, and have supposed, that a Cubick Foot of Water weighs 76 Pound, which Foot containing 1728 Cubick Inches, and divided by 76, gives an Ounce and 13 Grains, which is the Weight of an Inch,

Inch Cubick of Water, the Weight therefore of 233 Grains, is as $\frac{233}{253}$ or thirty five Parts of a Cubick Foot.

THE Area then of a Square, whose Side is seven Inches and upwards, is forty nine, by which if you divide the Quantity of Water, which it is carried off in Vapour, viz. $\frac{31}{8}$, the Product is $\frac{31}{862}$, or $\frac{1}{33}$; from which appears, that there was fifty three Parts of an Inch carried off in that Experiment, and is as plain a Demonstration as such an Experiment will produce. How great a Quantity of Vapour may be exhal'd from Bodies of Water, which are larger (enough to supply, as may be inferr'd from that learned Author) when the vast Extent of the Ocean, and other watery Bodies, are consider'd, not only Rains, Dews, &c. but also all large Springs when they lodge themselves on the Tops of Hills and Mountains, as has been described in the Paragraphs before going.

THUS have I, with as much Industry and Perspicuity as I could, summ'd up the Opinion of this great and learned Man, being unwilling to take upon me to overturn what he has thus judiciously set down. However, that I may pursue my intended Method, I must, with all who have consider'd any thing of the great Effects which Vapours produce in many Parts of the World, own how largely they contribute to the Formation of Rains and Dews, in so much that we are told by Mr. *Warren*, in the *Act. Lips. Page 98*. That the Clouds and Fogs hanging over and about the Mountain called the *Pike of Teneriffe*, do run down every Day about Noon in such vast Quantities, that they do abundantly supply the Place of great Rains, which never fall upon other Parts of that Island: And the same is confirm'd by the learned Doctor himself, who concludes from what he had before laid down on that Head, what great Quantities of Water must be collected in a little Time on Mountains which are larger; such as the *Pyrennees*, the *Alps*, the *Apenine*, and *Carpathian* Mountains in *Europe*; the *Taurus*, *Carcasus*, and *Immaus*, in *Asia*; with others of great Note in *America*.

BUT although Vapours have so great an Effect, as to supply some of those Parts of the World so plentifully, that they have no Occasion of Rain itself, yet common Experience tells us, that in *England*, at least, there is no such Thing; nor do Vapours contribute much (if any thing at all) to the furnishing of Springs or Brooks; nor are they to us of any other Use, than that by their Sublimation into the upper Regions of the Air, being there condensed into Rain or Dews, they descend, and fall down gently again: Nor was it ever observ'd, that the thickest Dews, Fogs, or Vapour that ever fell with us, did at any Time enter ten Foot into the Ground, or do

any other than lodge itself in woolly hairy Substances, on the Surface of the Earth: Besides where such large Caverns are to be found, as describ'd by the learned *Nieuentyl*, *Fig. II.* of the next Plate, is (amongst all the caverous Observations which we have made) hard to be found; and if Rain does not contribute to the Original and Enlargement of Springs, (which shall be, in its proper Place, prov'd it does not,) how is it possible that Vapour or Dews should do, (especially in *England*,) where their Strength is not so great as it is in foreign Regions.

BESIDES, it must be suppos'd that all Vapour and Mist falls (as Rain does) against one Hill, as well as another; and why then should not the Hills in *Salisbury Plain* emit the same Quantity of Springs, as other Countries. More than that, there must be great Quantities of Vapour; and it ought to be continual, and immediately succeeding one another also, to supply the Streams of a perenial Fountain, which runs stronger in the Winter, when few or no Vapours fall only in Rain, (and when there are few or none of those repeated Exhalations,) than it does in the Summer, when they abound most; so that if these Vapours contribute any Thing towards the Supply of Springs, it must be in mountainous and woody Countries, where lodging on the Summits and Tops of the Trees and Hills, they lique and run down into the Chasms of the Earth, and after that break out, and disperse themselves for the Use and Benefit of Mankind, in the Manner so often describ'd.

THE Curious Monsieur *Marriotte* (with some others of our own Country) are of the Opinion, that Springs have their Rise from Rains only, and produce Experiments, wherein, by Calculation it appears, that the Rains which fall in a Year, are more than enough for the Supply of Springs; one of which he tells us was made at his Request by a skilful Man at *Dijon*, who plac'd near the Top of his House a square Vessel of about two Foot Diameter, at the Top of which there was a Pipe, which convey'd the Rain that fell into it into a Cylinderick Vessel, where it was easy to measure it as often as it rain'd; for when the Water was in the Cylinderick Vessel, there was very little exhal'd for five or six Days.

THE Vessel of two Foot Diameter, was sustain'd by a Bar of Iron, which advanc'd above six Foot beyond the Window whereon it was placed, and so fixed that it might receive only Rain-Water which fell immediately upon the Breadth of its opening, and that there might not any enter but what was to fall according to the Proportion of the upper Surface. The Result of these Experiments was, that

that in a Year there might commonly fall in Rain-Water, to the Height of seventeen, (though others of our own Country say nineteen Inches,) as does the Anonymous Author of a *French Book* (mentioned by *Marriotte* and *Dr. Plott*;) entitled, *De l'Origine des Fontaines*, by Experiments which he had made three Years successively.

BUT let it be supposed (with *Marriotte*) that less than these Observations, and that in a Year there falls Rain only to the Height of fifteen Inches. Upon this Supposition there would fall upon a Fathom in a Year forty five Foot Cubick of Water; and supposing that a League contains 2300 Fathoms in Length, and that a square League contains 5290000 superficial Fathoms, which being multiplied by 45 (the Number of Cubick Feet that fall upon a Fathom in a Year,) the Content is 238050000 Cubick Feet, which according to *English* Computation, is about 2380500 Hogsheads, supposing that ten Cubick Feet *French* of Water makes a Hoghead, which it does, and more.

AGAIN, *Marriotte* observes, in Relation to the Strength of Springs, that the Content of the whole Extent in Land, on the *Seine* and other Rivers, is sixty Leagues in Length, and fifty in Breadth, which makes 3000 square Leagues, the Product of which being multiplied by 238050000 amounts to 714150000000 Cubick Feet, which being divided by 10, as before, amounts to 71415000000 Hogsheads *English*, which the Lands that furnish the Waters of the *Seine* at *Paris* receives from the Rain in one Year.

Now as to the Expence of this Water, *Marriotte* calculates it in the following Manner: The *Seine*, says he, above *Pont-Royal*, when it touches the two Keys, covering but very little of the Extremity of Land on both Sides, for about the Breadth of four hundred Foot, and five Foot deep in the Main, is then in its mean Bulk; and its Velocity at the Surface is such, that it goes 150 Foot in a Minute, but it goes 250 Foot when the Waters are at their greatest Height; for a Stick which is carried in the Middle of the Stream, goes as swiftly as a Man who walks very fast, which may be said to be 15000 Foot in an Hour, and consequently 250 in a Minute, which is full four Foot in a second. But because the Bottom of the Water does not go so swift as the Middle, nor the Middle so fast as the upper Surface, (as will be hereafter proved,) let it be said that its mean Velocity is 100 Foot in a Minute.

THE Product of 400 Foot, which is the Breadth, being multiplied by five, the Middle or mean Depth gives 2000; for it is eight or ten Foot deep in some Places, in others six, three, or two, and the

Pro-

Product of 2000 by 100, makes 200000 Cubick Feet; and consequently there passes through a Section of the Bed of the River *Seine* above *Pont-Royal* 200000 Cubick Feet in a Minute, 12000000 in an Hour, 288000000 in twenty four Hours, and 10512000000 Cubick Feet, or 12000000 Hogsheads *English* in a Year, which is not the sixth Part that falls by Rains and Snows, which as has been before calculated, is 714150000000 Cubick Feet, or 71415000000 Hogsheads *English* in a Year.

It is plain then (says our very curious Author) that if the third Part of the Rain-Water was to be exhal'd up in Vapours immediately after it fell, and if half of the rest was to remain some Time upon the Surface of the Earth to keep it wet, as it ordinarily happens, and some in the subterraneous Places under great Plains; and if only the Remainder soak'd in through little Conducts to make Springs underneath, or upon the Declivity of a Hill, there would still be enough to produce those Springs and Rivers as they now appear; and if you take eighteen Inches instead of fifteen in the above mentioned Calculation, you will have instead of 714000000, the Sum of 856980000000 Cubick Feet, or 85698000000 Hogsheads, which is eight Times as much as is expended in the Current of the River *Seine*.

FROM all which appears, the great Possibility there is that the Original of Springs may be from Rain, Snow, &c. But yet as specious as it appears to be, there are a great many Objections to be brought against it, some of which I shall name in their Course: As, first, that if Rains be the Occasion of Springs, how comes it to pass, that some very large Tracts of Lands, such as we have in the West of *England*, have but few, and some but very small Rivulets and Streams of Water, whilst others more Northward, abound in very large Rivers, there being no Rivers, either in *Hants*, *Wilts*, or *Dorset*, I may add *Somersetshire*, that are comparable to the *Trent*, the *Humber*, or the *Severn*, though the Tracts of Land that are to supply them, are much larger than in any of these Countries. And it is generally observed, that these Western Counties produce as much or more Rain than any other Counties of *England* do, on Account of their being situated so near the Western, or *Atlantick* Ocean, which produce such Varieties of Wind, Rain, &c. And indeed the Observation is so general, that the largest champain Countries produce the least Springs; whilst others of less Amplitude, such as *Gloucester*, *Salop*, *Nottingham*, and other Counties, produce them in much greater Quantities.

THE Reverend and Ingenious Mr. *Deerham*, whose Works are now so justly admired, on Account of the Accuracy of his Style, and the Curiousness of his Observations, in his *Physico Theology*, Page 50. (amongst many other strong Reasons, concludes from the Perennity of divers Springs, which always affords the same Quantity of Water, that Rains can have little or no Effect, nor do they contribute much, if at all, to Springs. And of these Sort of Springs, he tells us, there are many to be found every where, but particularly singles out one in the Parish of *Upminster*, where he lived.

THIS in the greatest Droughts was little, if at all diminished, altho' the Ponds all over the Country, and in adjoining Brooks, (which had really their Original from Rain and Land-Floods,) were dry for many Months together; as particularly in the dry Summer Months of the Year 1705. And in the wettest Seasons, such as the Summer Months, and others, which preceded the violent Storm in *November* 1703. (See *Philosophical Transactions*, N^o. 289.) it was not observed, that there was any Increment of its Stream, excepting only from the violent Rains falling therein, or running down from higher Lands thereinto; which discoloured the Water sometimes, and made an Increase only for a Day or two, or sometimes but of a few Hours Continuance. But now if that Spring had had its Origin from Rain and Vapours, there would have been such an Increase and Decrease of the one, as there should happen to be of the other; as it actually is, in such temporary Springs, as have their undoubted Source from Rain, Snow, &c.

BUT besides this, there was another considerable Thing in the *Upminster* Spring, (as it is in a thousand others;) which was, that it breaks out of so inconsiderable a Hillock or Eminence of Ground, that can have no more Influence in the Condensation of Vapours, or the Dropping of the Clouds, (which the Maintainers of this Hypothesis suppose,) than the lower Lands about it have. By some critical Observations which were made by this curious Observer of Meteorology with a portable Level, his House stood 80 or 90 Foot higher than the lower Water-Mark in that Part of the River *Thames* which was nearest to him; and that Part of the River being scarce thirty Miles from the Sea, he guess'd (and was afterwards more fully convinced of it by Experiments) that he could not be above 100 Foot above it: The Spring he judged to be nearly with, or but little higher than where his House stands; and the Lands from whence it immediately proceeds, about 15 or 20 Foot higher than the Spring; and the Lands above that of no remarkable Height. And,

indeed, by actual Measure, one of the highest Hills in that County was but 393 Foot high; and by other Experiments he was convinced, that neither that nor any other Land in *Essex* was above 400 Foot above the Sea. Now what (says my learned Author) is so inconsiderate a Rise of Land for the perennial Condensation of Vapours? or, I add, such a small Hillock as is before described, for the Maintenance even of so inconsiderable a Fountain as what was just mentioned? or indeed the whole County, to the maintaining of so many Fountains or Rivulets as are there found? But tho' that should be allowed to be possible by the Calculations before mentioned, yet how should it come to pass, that that and other Springs, should keep on in one constant and uniform Course, not increased by great Rains, nor decreased by dry Weather, (if Rain alone was the Origin and Cause of them,) is hard to conceive.

BUT this is not all, there being other Objections that offer themselves against this Hypothesis of *Mariotte*, and his Followers: One of which is, That though the Rain that falls in or near the River *Seine*, &c. does (as appears by Calculation,) sufficiently produce Water enough to supply that River; yet there are other Places where the Springs are so large, and where there is no supereminent Ground, that 'tis impossible that they can have their Original therefrom. *Jo. Bapt. Ricciolus in Almegisto novo, Lib. II. Cap. 13.* as quoted by Doctor *Plot*, Page 74. of his Treatise *De Origine Fontium*, tells us, that there flows into the *Adriatick* Sea in one Hour, 18000000 Cubick Paces of Water; which if he means, as he certainly does, Geometrical Paces, which are five Times the Quantity of our Cubick Feet, it makes 90000000 Cubick Feet, which is near eight Times the Quantity, that according to *Mariotte*, the *Seine* gives: And this River, says my often quoted Author, is scarce to be compared to the *Thames*, or the *Severn*, or even the *Rhone* in *France*, which is (it is to be supposed) a great deal larger than the *Seine*, which makes but a poor Figure compared to our *Thames* at *London*, or the *Severn* towards *Bristol*, as the Maps demonstrate. This, I say, shews the Inequality, at least, that there is in the Fluxion of Springs in different Places, though there are, or may be Lands of equal Superficies to supply the one as well as the other. And certain it is, that there are Lands very large and voluminous, where there are few or no Rivers at all; and in other Places prodigious large Rivers, where there is no supereminent Ground, the *Danube* it self rising, as some Authors affirm, in the Middle of plain Fields. But of this, more elsewhere.

FARTHER, that Rains have little or nothing to do in the Original and Rise of Springs, I take from the following Observation, which I
my

my self have lately made at *Chelmsford* in *Essex*, where there is one of the most constant and finest Springs I ever saw, especially in a Town.

At the Conduit, which is in the Market-Place, there are three Pipes, from which the Inhabitants fetch their Water: These three Pipes, supplied, as they are, by a five Inch Main, emit one Hoghead and half and four Gallons in a Minute, 12272 Hogheads and 48 Gallons in one Day, 69469 Hogheads three Gallons in a Month, 830191 Hogheads 39 Gallons in a Year. This Account was taken in the Summer, when the Pipes might be supposed to afford less Quantities than in the Winter.

ACCORDINGLY it is observed, that when another Spring, which lies somewhat above the other, sends out its Water, which it does about the Autumnal Equinox, which this Year 1727 happens about the Fourth of *October*, and is the Occasion why the Coronation of his present Majesty King *George* the Second, is deferred till the 11th of this Month, that then by the Union of the Spring above it, the Conduit will run half a Hoghead in a Minute more than it did before.

Now the Reason of this Spring's being dry, at least, that it does not afford much Water in the Summer, and so great a Quantity in the Winter, is with great Probability of Truth owing to the Lowness of the Tides all the Summer: For as for Rains, let them happen to be never so great, they never enlarge the Quantity of Water the Springs send out in the wettest Summer; nor does the Spring give any Thing less in those Summers which are the driest: So that it appears plain enough, that it is the high Tides which happen at that or any other Time of the Year, which gives Birth to that uppermost Spring, according to the Height of the Sea, and the Gravitation of the Atmosphere. And this is the Opinion of the Inhabitants who have long observed it.

As to the Manner how Waters are raised up into Mountains, and other high Lands, and which has all along puzzled so many great Men, (Mr. *Deerham* says,) may be conceived by an easy and natural Representation, made by putting a little Heap of Sand or Ashes, or a little Loaf of Bread, into a Basin of Water, where the Sand will represent the dry Land, or an Island, and the Basin of Water the Sea about it; and as the Water in the Basin rises up to or near the Tops of the Heap in it, so does the Water of the Sea, Lakes, &c. rise in Hills: Which Case he takes to be the same with the Rise of Liquids in capillary Tubes, or between contiguous Plains, or in a Tube fill'd with Ashes; of which the industrious and compleat Artificer in Air-Pumps, Mr. *Hawksbee* has given some not contemptible Experiments in his *Phys. Mechan. Exprim.* Page 139.

which shall be exhibited in their proper Places, and proceed to the farther Examination of these and other Hypotheses which lie before us.

Robault, in his *Physicks*, Part III. *Cap.* 10. in his Account of Springs, says, That tho' one can't think of their Original without Admiration, yet that the Enquiry was not very difficult.

For if we consider, (says he,) first of all, that there are few or no Springs which ever grow dry, and that Rivers, which are composed of those Springs, are continually flowing into the Sea; it is easily inferred, that the Sea supplies all those Fountains with Water by the subterraneous Streams which she distributes through all the Veins and Pores of the Earth.

If (with this ingenious Author) we come to a more particular Account of the Manner by which this Water may be brought to Fountains, it is certain, that the exterior Part of the Globe is divided into an infinite Number of Channels, through which it is easy to be conceived, that Water may, by its own Gravity, and the Fluidity of its Nature, spread it self even from Places of the greatest Distance from the Ocean.

It is visible, (says he,) that all ponderous Liquors, when they are included in great Vessels, collect themselves into a Level, and no Part of them can be higher one than another. The Sea Water in *Burgundy* and *Champaigne* for Example, out of which the Fountains of the *Seine* arise, and of which that River is composed, which empties it self at *Havre de Grace*, being all on a Level; it is plain that that Water can't be raised any higher; and yet when the Countries before mentioned, where these Springs spread themselves by the Declivity of the Course of the same *Seine*, are higher in their Superficies than the Sea, there are small Veins of Water which belong and send the Water to those which lie higher; and for that Reason must, by some Means or other, rise much above the Height of the Superficies of the Water therein. It therefore remains, that we find out the Method by which Water may be raised from those low Caves into the Tops of Mountains; all which shall be done in its proper Place. And to proceed:

HAVING thus traced the Opinions of many Authors, both antient and modern, with their Arguments *pro* and *con*, as to the Original and Rise of Springs, it appears that such is the different Sentiments which they are of, that it is still something of a Doubt from whence it is that their real Source is: I come now to what I have all along chiefly aimed at, and which, with humble Submission to better Judgment, I take to be the true Original of all Kinds of Springs, after having summ'd up all that has been said on this Head; as, first,
That

That it cant't be from Air, (as *Aristotle* and his Followers would have it,) nor from Vapours, either from above or below, (as the *Cartesians*, and some of our own Countrymen have suppos'd,) it being a Truth even to be denied, that are any such Caverns, or if there are, that there is such a sudden Mutation of Elements, or that either of them should afford Quantities of Water sufficient for the Supply of such large Fountains, which are found in many Places, in a regular and uniform Succession.

THAT their Original is not solely, if at all, from Rain or Vapours, (as *Marriotte* and others have suppos'd,) has been made appear by that curious Observer of Meteorology Mr. *Deerham*, whose Observations thereon are exact, and beyond all Dispute; and that there are many Hills and large campanious Countries in *England*, and other Parts of the World, though the same Quantity of Rain and Vapours fall on them which do on others; yet they afford few, if any Springs at all; a certain Indication that the Rains which fall on those voluminous Tracts of Earth, are chiefly drank up by the Herbage, or dry Soils of those Plains, and don't contribute (if at all) to the Increase of perennial Springs.

BESIDES all which, and to the Reasons before set down, that neither Air nor Vapours, nor Rain can be the Cause of Springs, I add what Experience every Day shews us; and that is, in the Digging of deep Wells through those almost impenetrable Rocks and Beds of Clay and Chalk, with which Well-Diggers generally encounter. A noble Lord, with whom I have the Honour to be very well acquainted, in *Gloucestershire*, has been some Time in digging one of them; and by all the Observations the Diggers could make, they would be oblig'd to go above a hundred Yards deep before they came to Water. Now, if Vapours from above, or Rain, were the Original of those Springs, they would, according to the Hypotheses of its Authors, subside, and break out on the Tops or Sides of the Hills thereabouts, there being at least three or four thousand Acres of Land which lie on the same Level that this Well is, near a thousand Acres whereof are Wood, the Top or Surface whereof being also a loose rubbelly Rock, and so consequently possess'd of all those Properties which *Marriotte* recommends as conducive to the forming of good Springs, to the Maintenance and keeping up of which those impenetrable Rocks, with some Strata's of Clay, that are generally intermix'd with them, are conducive also; I mean in the sustaining them upwards towards the Surface, and obliging them to break out there: But more certain it is, that those heavy Rocks, and Beds of Clay, Chalk, &c. depress such Springs in their Ascent, and is the visible Cause

Cause why all Earths which abound with Materials of so close a Contexture, never afford much Water, if any at all; and it must be observ'd also, that the Scarcity of Springs which is in many Western Countries, where there are greater Plenty of Rains from the *Atlantic* Ocean, than are in others more Easterly or Northward, must be owing to this Cause.

To this Account of Springs not arising in Plenty in Countries where much Rain falls, being drank up by the Herbage, Trees, &c. may be added, that there are other Places where they abound, having little or no Rain at all, particularly in the two Islands of *Maio* and *Rotunda* in the *Ionian* Sea, in the *Thracian Bosphorus*, and other Places, where, according to the Account of the very ingenious Sir *James Young*, of *Plymouth*, as we find it in *Hook's Lecturas Cutlerian. de Potentia restitutiva*, p. 28. it did not rain for a long Time, yet the Springs ran freely all the while.

To this may likewise be added what Dr. *Plot*, in his *Treatise de Origine Fontium*, observes, that Springs have not their Original from Rain, as many would make the World believe; for that the nearer you go to the Sea, the more brinish and salt, and the farther you go off, the sweeter Springs are. This is an Observation to be found not only in *Hieron. Cardani's Treatise de Subtilitate*, (of which more by and by,) lib. 2. p. 166. Edit. Basil. Anno 1582. but also by Sir *James Young* elsewhere mentioned, who was curious in Observations of this kind: For which see *Hook's Lecturas Cutlerian. de Potentia restitutiva*, p. 31. The same may be also discover'd by any Gentleman who travels towards any of our maritime Ports, since the nearer you come to them, the more brinish and salt they are, and so brackish and bad, that within a Mile or two, and sometimes a farther Distance, even six or seven Miles, the Water is so unfavoury, as that an Inlander, who is not us'd to them, can by no Means relish them; and their Malt-Liquor in particular, is so effected by it, that it is undrinkable by any but those who are continually us'd to it. Some particular Springs, indeed, there are, which are sweet; but they are in all Probability such, whose Canals proceed from some distant Hills, it being often found that good and bad Springs are found nearly contiguous to one another. But this can't be drawn into Precedent, nor sufficiently maintain the Hypothesis of those who aver, that Springs derive their Origin from Rains, &c. And if it be made appear, as I think it is, that cold Waters are not produc'd by Rains, much more will it appear that hot Water, and those which are salt and bitter, cannot.

CERTAIN it is, upon the undoubted Credit of very worthy Men, that there are not only Springs but Rivers of that Kind, as * *Peter Martyr*, in a Treatise of his, sets down, of a River in the *West Indies*, which is so large, as that a large Vessel may ride upon it; and in the mean time, it is so hot, that you can't touch it with your Finger. Of the same Kind also there is a Fountain in *Islandia*, as the aforesaid Doctor has it, so hot, that no Fire can make it hotter. Another also of them is in the Island *Japan*, which, as *Caronius* witnesses, is three Times hotter than 'tis possible any Fire can make it, as † *Varennius* in his Geography sets down.

BUT it is needless to go far for Examples of this Kind: Those whose Misfortunes lead them to the Hot Baths of *England*, and other *European* Countries, are Witnesses of the Truth of what I am here asserting, I mean as to their Heat, which though not so large and extensive as those before mentioned, yet is equal to what a moderate Fire will do. Let then those Advocates for the Production of Springs by Rain, tell us, how it comes to pass, that one Spring is so hot, another so bitter, and a third so salt, that it is impossible for any Body to use them with Pleasure. Can they proceed from Rain, or any other superficial Cause? or is there any Reason to believe they can receive, or be endued with any of those Properties by any other Means than by their ‡ Ascent, and Percolation through those Veins of Earth that gives them those saline, fervid, or bitter Properties, though they flow regularly, and in like Manner as all other perennial Springs do? Nor is Rain of any other Service, but to spoil them, as those that stay long at the *Bath*, and other Places of that kind, can very plainly discern, and which generally puts a Period to those salutary, and sometimes pleasant Meetings.

I MIGHT add a great many more Reasons why Springs can by no Means owe their Original to Vapours, Rain, &c. but that I haste to the next Chapter, which shews from whence Springs, with more Probability of Truth, do arise; in which the Arguments which have been omitted in this, will naturally fall in.

C H A P.

* Sommario de l'Indie occidentale, del S. Don Pierro Martyre, cap. 7. p. 6. Stamp. ven. L. an. 1565. ut vult D. Plot de Origine Fontium, p. 80.

† In Japonia fontem adeo fervidum prorumpere scribit Caronius, ut ignis vehementissimus licet fervore nulla aqua ad eum Gradum perducı possit; triplo etiam diutius retinere aquam, quam nostra aqua Calefacta consueverit. Varen. Geog. Lib. 1. cap. 17. Prop. 8.

‡ Causa & generatio thermarum est. Prop. 8. Admixtio sulphurearum particularum dum aqua per Suterraneos meatos fertur ut testat idem Varennius, Lib. 1. Cap. 17. prop. 8. præd.

C H A P. III.

Of the Opinion of those who, with more Probability, attribute the Original and Rise of perennial Springs to subterraneous Causes, &c.

I Come now in this Chapter to give the most probable Account I can of the real Original and Rise of Springs, and shall, with Dr. Plot, divide the various Kinds of them in the following Manner:

First, SPRINGS, which are temporary, and do not flow continually, which are again divided into

Those which flow regularly, yet are uncertain, as proceeding from Rains; or certain, though periodical, as flowing at some certain Seasons, yet dry in others.

Or irregular, which are also those that are annual, which flow something every Year, though at uncertain Times of it; or septennial or decennial, which flow or are deficient septennially or decennially.

Secondly, SPRINGS, which are perennial, and flow without ceasing, which may be again divided into

Those which are limpid, pure, and unmix'd, which flow either Guttatim, or Drop by Drop, or precipitately.

Or those which are mix'd, and abound either with Salt; of which some are warm, as is seen in Hot Baths.

Or with Pitch or Sulphur, and are cold, as in Salt Pits, or in other medicinal cold Waters.

Of all which I shall proceed to give as succinct Account as I can.

The Original of the first of these is manifestly owing to Rain or Snow; and their Periodical Flowings generally proceed from great Snow or Rains, which fall at certain Seasons of the Year on some large contiguous Plains, or hilly and mountainous Grounds; and to this Cause, in a great measure, may be ascribed the fourth Sort of Springs, or perhaps

haps rather to the Experiment of the *Tantalus*, as described by Dr. *Desaguliers*, *Philosophical Transactions*, N^o. 384. which will (in the next Chapter) be more fully handled. Those which flow and fall off every seven or ten Years, are indeed more difficult to account for than any : But what I most chiefly aim at, is, the accounting for those that are plac'd in the last Class, and which are perennial, and flow always in a regular uniform Manner, and produce those large Rivers with which the World is so well water'd, leaving those, of which hot and cold Baths are compos'd to Physicians, and others whose more proper Business it is, to expatiate on that Subject, having always in View that which many learned Authors have long ago believ'd, that those Kind of Springs which are perennial, have their undoubted Origin from the Sea, and which passing through the Veins and Ducts of the Earth in a due and regular Motion, are by the continual Pressure of the Atmosphere, and the Gravitation and Impulse of the Moon thereon, rais'd up to the Tops or Sides of the highest Hills, though exceeding the precise Laws of Hydrostaticks.

An Fontes oriuntur ex Mare, has been a Theme which has long subsisted in Schools, nor has it been yet, I think, sufficiently confuted, carrying, in my humble Opinion, the greatest Probability of Truth of any Hypothesis whatsoever, and towards the Augmentation of which, perhaps, Rains, Snows, Mists, Vapours, and other tumid Exhalations, may contribute something; for were it not so, and that there was a watery Foundation below, that does stop and impede all those Waters that fall from above, Water itself being of so ponderous a Nature, would (as *Marriotte* otherwise observes,) sink down towards the Center (rather than break out of the Sides) of Hills; but when Waters, that come from above, meet with those that arise from below, the Interception, or Clashing of the one with the other, is the undoubted Cause that they break out with that Violence they do, on the Sides of Hills; and the Reason why some Hills abound with Springs more than others, seems to be on account of those Vents or Passages of rocky Stone and Gravel, intermix'd with Sand or rubelly Clay, all which give way for the Springs that are below to ascend, as they do the Waters above to descend for that Purpose; whilst all large campaneous Countries, which have no such Variety of Materials, through which the Springs can pass, are either by a thick solid Body of Stone, Chalk, or Clay, so chain'd down, that they can't rise from below, which Bed also keeps those that are above from descending down, any other than to satisfy the Drought of the Earth, and the Herbage that grows thereon; so that

(to speak in plain Terms) what by the one, or what by the other, there is no Water to be had, unless you dig through those deep and dry Rocks to a very deep and low Situation, communicating, as may be reasonably suppos'd, with Rivers, if not the Sea itself; the Salt and Brackishness whereof is lost in its Percolation, through the Pores of the Earth.

THIS seems also to be the Opinion of some great Men, since *Cardan*, in his Treatise *de Subtilitate*, *Lib. ii. p. 166.* before mentioned, says, (to use his own Words,) *Putei Effossi quo magis à mari distant, eo minus sunt Salsi*; and my Lord *Bacon* somewhere affirms the same; and that *Cæsar*, which is confirm'd also by *Hirt. Panf.* in his *Comment. de Bello Alexandrino*, cap. 9. made Experiments of it when he was besieg'd in *Alexandria*, and thereby sav'd his Army, which was in Danger of perishing; and that it was Sea-Water he likewise affirms, because the Pits which he digg'd, rose and fell as the Tide did, as do the Waters in or near the Sea-Port Towns of many Places of *England*, as is elsewhere observed.

OF this Kind also was a Spring or Rivulet somewhere in *Carnarvonshire*, mentioned by *Camden*; another there is, as *Varennius*, in his *Geography*, *Lib. I. cap. 17. prop. 17.* witnesses, which he calls *Marsaca vasconum*, (the Translation of which I cannot find in my Dictionary,) where the Tides of the *Garonne* flow upon a Level to *Bordeaux*; a third also there is, which *Gassendus*, in his *Physicks*, *Seet 3. Memb. pr. Lib. i. cap. 7.* mentions, in a little Island near the Banks of the *Timavus*, a great River of the *Carni*; but these are nothing to compare with one in the Province of *Connaught* in *Ireland*, which, as (*Dr. Plot*, p. 102. of his *Tentamen*, &c. sets down,) being on the Top of a high Mountain, exactly flows and reflows with the Sea-Tides, and yet is said to produce sweet Water. Like to this also is a Spring which they call *Lanzara*, amongst the Mountains of the *Cabretti*, in *Spanish Gallia*, which, as *Varennius* says, *Lib. I. cap. 17. prop. 17. prædic.* flows and reflows in that Manner, tho' it is twenty Leagues Distance from the Sea. To which may be added, (one which is more remarkable than all the rest,) which is the Mountain *Erminium* in *Lusitania*, or *Portugal*, which raises its Head, (as *Vasconcellus*, cap. 5. of his Description of that Kingdom has it,) like a Pyramid, and especially in that Part, which the Inhabitants, for Distinction sake, term *Montem comtari*, as I find it in *Plot*, p. 103. In the very Tip-top of which Hill, (to use the Words of *Vasconcellus* himself,) "There arises a Lake, which has many Passages in its Circuit, that with great Punctuality and Observance follows the reciprocal Motion of the Tides in the Sea."

BUT

BUT we need not go so far to find out the Correspondence there is between the Sea, Rivers, and subterraneous Wells and Ducts of Water, there being (besides many other Places which might be named) several Wells at a little Village called *Spittle*, about ten Mile beyond *Lincoln*, in the Road to *Barton* and *Hull*, the Surfaces whereof rise and sink in the same Manner as the River *Trent* does, though it be near fifteen or twenty Miles off; and so remarkably true it is, that the late Lord *Castleton*, who had great Possessions on the Banks of the said River, and liv'd seven or eight Miles, or more Distance than *Spittle*, never sent any farther than that Place to know the State of the River, and whether or no his Cattle which were feeding at that great Distance, were in any Danger of being drowned by the Overflowings of it; from all which, with the industrious *Plot*, (p. 103. *prædic.*) it may be certainly pronounc'd, *That there is a certain Commerce or Correspondence which passes between Springs and the Sea.*

THE ingenious and learned Mr. *Ray*, (one of the greatest Sticklers for the Derivation of Springs from Rain,) in his Treatise of the Dissolution of the World by Fire, allows that there are those subterraneous Passages, which *do, and must necessarily communicate with the Sea*, (Vid. p. 69. of that Treatise,) and instances that of the *Caspian* and *Mediterranean* Seas, which receive into themselves many and great Rivers, and yet have no visible Outlets, nay, that the last receives also abundance of Waters from the great Ocean, running in at the *Streights of Gibraltar*: And therefore, by subterraneous Passages, must needs discharge theirs into the great Abyss or Fountain of Waters under them; and then, (but by which Way he does not tell us,) they break out into the Ocean again; and his main Objection (as indeed it is the chief of all those who are against the Hypothesis I am endeavouring to explain) is, how it can possibly be, since Water is well known to keep to its Level, and cannot ascend to any great Height above the common Center, that is, than the Superficies of the Sea is, much less, says he, is it able to force its Way, remove such Obstacles, and break open such Passages as it does.

To which I answer, that this ingenious Author does not seem well acquainted with the successive Laws of Pressure or Pulsion, or rather how Liquors ascend in capillary Tubes, all which I shall endeavour to explain in the next Chapter. The specifick Gravity of the Earth being so much greater than that of Water, is, I humbly conceive, a sufficient Reason to induce any one to believe, that this Ascent is not only probable, but absolutely reasonable and necessary, nor does

36 *An Introduction to a General System*

the Account which Sir *Thomas Willoughby*, in his Coal-Works, gives, invalidate, but rather makes for that which I have been all along giving of Springs, which is as follows: "If the Springs, (says this Noble Gentleman,) lie before you come to the Coals, they carry the Water away," *i. e.* (as I apprehend he means,) *if there are constant Springs which break through the Chasms of the Coal from below, they stop the Rain-Waters, and carries them all away:* But if there be no ascending Springs, it falls by the Laws of Gravity into the Works in greater or less Quantities, according as the Rains fall. But this ingenious Author is of another Mind from me, and says, that this is a farther Proof to him, that Springs are fed by Rain-Water. If he means Land-Springs or Top-Springs, he is certainly in the Right; but if he means those which are perennial, and flow constantly, he is as certainly in the Wrong, as has been demonstrated in the foregoing Chapter, in the Example of the *Upminster* Spring, the Account whereof was taken by Mr. *Deerham*, who has made Rain his favourite Study, and also that of *Chelmsford* in *Essex*, which was lately taken by my self, besides many others, which might be produc'd.

As to what Mr. *Ray* says of the extraordinary dry Summers which happen'd in 1654, 55, and 56. when our Climate was drier than it had ever been known in any Story, and which had dried up most of those Springs which had never been (in the Memory of the eldest Man living) known to be dry before, I answer, that at that Time, sure enough, also the Water was low, and the Tides never arose so high in the Sea, as they us'd to do, and which is the undoubted Occasion why one of the *Chelmsford* Springs (as I have already observ'd) rarely breaks out, at least, affords much Water in Summer. Nor is it to be doubted, but that the Account the Laborious *Heylin* gives of the great Drought, which was in the Days of *Constantine* the Great, which lasted thirty six Years, by which all the Springs and Torrents, or Brooks, were dried up, so that the Inhabitants were forc'd to forsake the Island, and seek new Habitations, for Want of fresh Water, proceeded from the above mentioned Cause, *i. e.* the Lowness of the Surface of the Sea; nor can it have a little Weight, when we consider, that though there should be small Eruptions of Water out of those perennial Springs, that the Dryness of the Ground is such, that they will immediately sup it up; nor must it be disown'd, that in all large Rivers, (such as our ingenious Author says were dry in 1654.) there are great Additions in all Gluts of Rain, by which they are much increas'd, (at least, as to distant Appearance;) but this is far from making perennial Springs.

BUT to return: It ought not to be omitted, as more fully confirming the Opinion aforegoing, of the Communication of the Sea with Land-Waters, that there are in Being in many Places, unpleasant Lakes which have no apparent Communication with the Sea, yet nevertheless abounds with Sea Fish, particularly one in the Valley of *Cajova*, in the Province of *Bayone* in *Spain*, called *Hagugabon*, which as *Peter Martyr* relates, (in his Treatise, *De Anglerii orbe novo*, Dec. III. cap. 8.) is thirty Miles in Length, and twelve in Breadth; and receives twenty four Rivers of fresh Water which fall from the Hills into it, yet by the Force of the Salt Water it sometimes ebbs and flows in such a Manner, and is so brackish and unpleasant, as to nourish what they call there the *Canes Carchinas*, and other Sea-Fishes; and as it vomits out some Waters, so it sucks up others, and that with so great a Violence, that even the Fishermen and their Boats are sometimes swallowed up in it. And he adds, that there is another in the same Province in every Respect like the former, but that it is less.

Varennius, (*Lib. I. cap. 15 prop. 7.*) in like Manner reports, that he found two large Lakes in the Island of *Cuba* in *America*, which was salt, and produced Sea-Fish, although it received at the same Time several fresh Water Rivers into it self. Another of the same Kind, adds *Varennius*, is in *Peru*, another in *Menuthia*; and that the Lake *Asphaltites* in *Judea*, though it draws the pure Streams of *Jordan*, yet its Nature is so changed by the supposed Correspondence it has with the Sea, and is so heavy, that nothing will sink it, and is by some, for that Reason, called the *Dead Sea*.

To all which may be added that which is called the *Caspian Sea* before mentioned, though it correspond with other Rivers of no common Magnitude, and receives all the Water of the *Volga* into it self, which produces such Quantities every Year, as would suffice for the Supply of the whole World, (if I may use Doctor *Plott's* Words,) yet it abounds always with salt Water, and produces Sea-Fish; nor does it ebb and flow less than the *Mediterranean Sea* it self. These and many more Examples which might be produced, are sufficient for our Enquiry, how it comes that those Lakes contract that Unpleasantness; and by what Method it can be that Sea Fish are carried thereinto; and how, lastly, it is that those immense Quantities of Water, such as are in the *Caspian* and *Mediterranean Sea*, which never transgress their Bounds, should be salt or brackish, unless it be granted that there are Passages, by which those Lakes hold Commerce or Correspondence with the Sea, and the Sea with them.

To

To omit much more which the industrious and learned *Plott* has produced to prove the subterraneous Correspondence there is between the Sea and Springs and Lakes, it remains next for us to give a short Account of some Springs Heads which are on high Hills, very far distant from the Sea, and to enquire by what Means Water rises to the Top thereof, Facts which have met with great Opposition from those who have declared in Favour of Rains, Snows, and other Hypotheses, and Doubts in many learned Men, whose Enquiry into this Part of Nature have been considerable, the Elevation of Springs to such great Height, much exceeding the precise Laws of Hydrostaticks, &c. All which I shall treat of in their particular Order.

THE first is, that it is certain there are many very high Hills, very distant from the Sea, which have no superior Tract of Land to supply them with, but must necessarily rise through its Mole or Body: Such is the Head of the River *Marsye*, which *Quintus Curtius* testifies, (*Historiarum Lib. III. in initio*,) rises from the Tip-top of a very high Mountain. Another there is, as *Cardan* relates, which falls from the Summit of prodigious high Rocks in the Island of *Maia*, upon the Borders of *Fife* in *Scotland*, though the same is not above two Miles in Circumference: As also another in the Island of *Bonnica*, not far from *Hispaniola*; for which see *Cardan de Subtilitate, Lib. II. page 92.* and *De rerum varietate, Lib. I. cap. 6. in initio.* And Sir *Robert Sibbald*, who wrote an Account of *Scotland*, in his *Prodrom. Pars prima, Lib. I. cap. 9.* tells us, that there was also a perpetual Fountain on the very high Top of the Mountain *Lominius*, in the Island of *Hoia* of the *Orcades*, on which there were three other Hills, observed for their Height, are admired by all Navigators at Sea, though far distant from it, and which appear like so many Piers or Landmarks: That there is in the Tops of one of the three, that rises out of the very Heart or Foundation of it, a very strong Spring. And the same I have been told is to be found on a Hill called *Pennichy*, or *Bend-up-high*, near *Aberdeen* in that Country, which runs continually, though there is no contiguous supereminent Plain that lies above it, or indeed near equal to it. The like I have also seen my self on the Top of a high Hill near *Marlborough* in *Wiltshire*, called *Martinsball*, or *Martincell* Hill; where, though the Ducts and Veins of the Earth are not large enough to emit a constant Stream, but to break out Guttatim, or Drop by Drop, as some perennial Fountains do, yet it has not been known to be dry in the Memory of any Body now living: And by its Clearness it is very likely to have its Origin through some small Veins which rise through the Hill, though its great Height and Distance from the Sea is also such,
that

that it can't send forth any large Quantities by any of the Laws of Hydrostaticks, or other Means.

To this Account of the Procedure of Springs out of high Hills, (which have none that are supereminent to them,) may be added the Account that an ingenious Surgeon, who used the *West Indies*, gave Mr. *James Young* of *Plymouth*, as may be seen in *Hook de Potentiâ Restitutivâ*, printed by *John Martyn*, Printer to the Royal Society, 1678. who assured him that there was a Spring which sent forth large Streams of Water, at which Ships were frequently furnished; and that there, as well as in the Island of *Mayo*, it rained but once a Year; that the Island from its Figure was called the *Rotunda*, and having no Ground which lay above it, could not by any Means produce a Quantity of Rain-Water sufficient to maintain that great Flux which was there so visible, even though it was to rain without ceasing. That in the Island of *Mayo*, of which Mention was made in the last, and which the aforesaid Mr. *James Young* also mentions, the Springs (as may be seen in the Draught he has given) are seen breaking out of a round Hill, at the upper End of that Island, higher than which there is no Ground, neither had it rained there for a considerable Time, though the Spring ran constantly and without Interruption quite through the Middle thereof. The same also may be observed in the *Insula Vectis*, or Isle of *Wight*, at a Place called *Appledore Comb*, the Seat of Sir *Robert Worsley*, where, though there is Land much above it, yet the Rains run off it with that Precipitation, that they never scarce enter the Herbadge, at least, so as to sink down, and make Springs.

To proceed with the learned *Plott*, it is worthy Remark what the most honoured Mr. *Boyle* observed on the maritime Coasts of *Waterford* in *Ireland*: He saw a Mountain, from the superior Clift of which ran a River of a moderate Amplitude, which had broke out there but just two or three Years before (without any manifest Cause) from a Morass which was at the highest Verticity of it; and from thence runs a great Ways, and affords a daily constant Stream to its Inhabitants; which if it had had its Original from Rains or Snows, he supposed would have shewed it self many Ages before: But from so sudden an Eruption it was most reasonable to believe, that it had but just then found (I may add forced) its Way through the Chasms of the Ground beneath, and being (if I may so express it) glad of its Liberty, flow'd on an uniform uninterrupted Succession. Moreover, *Scaliger*, (in his Treatise *De Subtilitate*, Lib. XV. Exercit. 46.) testifies, that there was near his *Villa* a large Spring, which came from the extream Top of a Mountain, though the Ground in no Part of the

the Neighbourhood afforded the same. He adds also, that there was a boiling Lake, which abounded with hot Springs, in a Plain over against the Top of the Mountain *Cinis*, in the *Alps*, to which spacious Plain there was no higher Ground which could administer Water to it, and so could not proceed from Rain.

A SECOND Thing I have to speak to in the Course of this Chapter, is to answer an Argument which the Dissenters to the Hypothesis (I am now endeavouring to explain) produce, who would necessarily have the Original of Springs owing to Rain; because, say they, (though by Way of Assertion without real Proof,) in all large Plains there are none any where found but what proceed from contiguous Hills. This has, in some Measure, been answered already, but will be more fully so in the Thread of this Account of Springs, wherein this Assertion will be prov'd to have no Foundation of Truth in it; since the ingenious *Boetius*, in his Natural History of *Ireland*, cap. 7. sec. 1. assures us, that there were many Places in that Kingdom from which large Springs and Rivers had their Rise, when at the same Time they were rarely to be found in Hills contiguous, or far off from them in that Part of the Country.

THE same Thing is also observable in the Rise of the Rivers *Rea* and *Isis*, which break out near the Town of *Fritwell* in the County of *Oxon*, which draw their Original from so humble a Plain, that there is scarce any Declivity sufficient for their Current, much less Supply. And this likewise is the Opinion of that curious Observer of Meteorology, the Reverend Mr. *Deerham*, in his *Physico Theology*, page 50. before recited.

BUT we need not rely altogether on the Observations made at home, where Springs arise in large Plains which have no Hills contiguous to them: The River *Pyramus* in *Cappadocia*, which although *Strabo* calls it *πλωτόν*, i. e. a navigable River, yet he relates that it breaks out of a Middle of a plain Field, as may be seen in his Geography, Lib. XII. page 536. of the *Paris* Edition, Anno 1620. Besides the large River *Tanais* proceeds from a large open Field in *Muscovy*, as *Agricola*, in his Treatise, *De Natura eorum quæ effluunt ex Terrâ*, Lib. III. in initio, describes.

To this may be joined what *Cluverius*, cap. 6. of his *Vindelicia & Niric*. writes of the *Danube*, the greatest River of *Europe*, whose Head, (says our Author,) though it flows perennially, and is twenty six Foot long, and eighteen Foot wide, yet it rises in an open plain Field in the Village of *Eschinger*, or *Donasching*, or as, *Jornandes* will have it, in the Fields of *Alemanicis*, and not as *Herodotus*,

tus, Tacitus, Plinius, and Marcellinus, have delivered it down, from the Foot of a Hill, or large Mountain.

To all this may be added, what I have read in an Account of *Switzerland*, wrote some few Years ago, as 'tis said, either by Mr. *Manning* or Mr. *Stanyan*, Ambassadors from the Crown of *Great Britain* to those States, that there was in that Country a Tract of Land, whether Hills, or no, I don't remember, which sends forth four Rivers, which take their Course four several Ways, not unlike the Production of those four famous Rivers of *Pison, Gihon, Hiddekel*, and *Euphrates*, said in Holy Writ, to have issued out of *Paradise* itself; a plain Instance that neither Rain or Vapours can be the Cause of those perennial and uninterrupted Springs with which the greatest Part of the World is water'd, but that they come from a much more deep and latent Cause.

THERE is a third Case, which ought to be spoke to more largely than I have as yet done; and that is, That Water passing with more Difficulty through the close clayey Veins of the Earth, few Fountains are ever observ'd there; when at the same Time they are never wanting in arenacious and stony Ground, through which the Water easily percolates; but that this does not make for the Supposition of Rain and Vapours being the Origin of Springs, but rather much against it, is already set down: And to confirm what has been offer'd on this Head, the ingenious Sir *James Young*, before mentioned, as we have it in *Hooke's Lectures, De Potentia restitut.* p. 39. and as is also before hinted at in the West Country, there is, as Dr. *Plott* observes, a large Tract of Land in the County of *Kent*, which is about seventeen Miles in Length, and five in Width, in which there is not one Spring to be found; and the same may be said, I dare say, in Thousands of other Places.

THE last Thing to be examin'd in this Narrative of Springs, is a Deficiency, that upon Deliberation appears to be in the Produce of Rain, as related by an Anonymous *French* Author, who is the same which, in all Appearance, is hinted at by *Marriotte*, but more plainly by Dr. *Plott*, in p. 69, &c. of his *Treatise of Springs*, where, according to that Author's Calculation, at nineteen Inches deep, which is four Inches more than *Marriotte* supposes, there does not (at *Willowbridge*, where this Observation was made) fall Rain sufficient for the Supply of the Springs in that Space, by 4811854 Hogsheads in a Year; to which, says the learned Doctor, may be added, that a vast Quantity of that Water which arises from Rain, Snows, &c. running, or to run out of Rivers into the Sea, are taken up in the Nourishment of Plants, and for the filling of the Pores of the Earth; which immense Quantity

tity the learned *Lister* and *Willis* have demonstrated, (as is seen in the Natural History of *Oxfordshire*, *Cap. ix. Sect. 95.* and in Mr. *Lister's* Treatise, *De Aquis Med. Angl. Exercit. Cap. xi*) that the major Part, if not all the Rain and Snows which fall, are again exhal'd up in Vapours, for the Creation of more Materials of that Kind, maintaining the same Circulation, or Ascent and Descent, in the open Air, as is beneath in the Bowels of the Earth. Besides, how comes it to pass that Springs should maintain their constant Current in scorching Deserts, where they have seldom any Rains, (as in those of *Arabia*, &c.) and in dry or cold Earths, or Fens; as also Woods and Groves, which when clear'd away, takes off that stagnant Air which is the Occasion of that Moisture and Dampness, with which those Countries were once rendered obnoxious, and which consequently (according to those Hypotheses which maintain Rains) should decrease their Springs, yet they still maintain their Current, and change the very Temperature of the Element; and that which was before cold and moist, is thereby forthwith made hotter, and more moderate, and so not capable of that Fund of Humid Air, Vapour, Rain, and which, according to them, is the Cause of Springs. So it is, that *Pliny*, in his *Natural History*, *Lib. xvii. Cap. 4.* notes of the Ground adjoining to the City of *Philippis*, which being clear'd away, and turn'd into Tillage, it grew dry, and chang'd the Genius of the ambient Air, &c. so that it might (from the Limpidity of its Streams, which flow'd continually, and without Interruption) be taken for the Habitation or Ambit of Heaven itself.

THE same also has happened in the Colonies belonging to the *British* Crown in *Barbadoes* and *Jamaica*, where the Woods being clear'd, and the Country expos'd to the Sun, there has fallen a less Quantity of Rain than was us'd to do, as may be seen in *Philosophical Transactions*, Numb. XXVII. p. 49. How much of that Kind has happened in the Bogs of *Ireland*, and in the Fens of *Lincoln*, and *Cambridgeshire*, need not be expatiated on; and thus from the Consideration that Springs have subsisted for several Years, where there has been a Decrease of Rain, and has not increas'd where there has happened a great deal; that there are many Springs in the World, which rise and fall as the Sea does; that there are many Lakes on Inland Grounds, which have no visible Communication with the Sea, yet produce Salt-Water; to which may be added, what I have omitted hitherto, that there are abundance of Shells, &c. which are found by digging in the Bowels of the Earth, which belong to the Sea: These Reasons, I say, confirm'd by Examples, ought abundantly to satisfy

satisfy the curious Reader, that there are such Hollows and subterraneous Ducts in the Bowels of the Earth, through which Springs draw their Original out of the Sea; and that they are not owing to any other Cause.

THE chief Thing which seems now to remain, is to give a more particular Account of the Methods by which Water is rais'd to the Tops of Hills.

Pliny supposes it to be thrown up by the Impulse of the Air, which is included in the Caverns of those Rocks and Mountains, as it were, through a Syphon.

Plutarch tells us, that from hence it is that Water issues out of new-broke Ground which is moist, just as the Blood does out of a Wound, or the Milk from the Paps of a Nurse; which, says an ingenious Author, is worthy of our Contemplation; and by this Means it is, that the Blood in all Scarifications is carried up, or rather extracted from the inner Mass, *viz.* according to the Laws of Attraction, or rather Pulsion, to which all Causes, both physical and mechanical, are now reduc'd.

Robault, in his *Physicks*, (*Par. iii. cap. 10*) supposes, with others, that Water has its Origin from the Sea; and that it is rais'd to the Tops of Mountains by the latent Heat of subterraneous Fires, which (whether central or despers'd) dissolves that Water into Vapour; and by this means it is (says he) that Water, which is in Places at a great Distance from the Sea, is drove by its own proper Weight and natural Fluidity, and so lifted up to the highest Hills; for when those Vapours can't move Sideways, and extend themselves which Way they please, because of others which are every where ascending, and endeavouring to expand themselves at the same Time, it is (says he) necessary that they should be carried upwards to the Tops of Mountains, and most certainly to turn into Air and Vapour, being future Materials for Rain, Snow, and Hail.

THIS being granted, it is easily understood, says he, that those Vapours, being brought to the superior Part of the Ground, and detain'd amongst the cold Particles which inhabit there, lose great Part of their Motion, and so can't ascend any farther, but are then turn'd into small Drops of Water, which by their Gravity flow out again; and by the Accession of other small Drops, added to those other which were before form'd, increase into a small Vein of Water, and flowing from thence, run into other Veins like it self, and, at last, into one large Vein or Artery of Water, breaking from thence, through some Passage or other, out of the Hill or Mountain, and then becomes a Spring

or Fountain of Water, which supplies all Reservoirs, Basins, Pits, Ponds, &c. that lie in its Way.

THIS, indeed, seems to be a fine Way of adjusting this great Affair; but, in answer to it, it must be said that the Existence of subterraneous Fires, if any such there are, serve for other Purposes than what this learned Author supposes they do, it being doubtful, if not mathematically and morally impossible, as *Marriotte* has in general observed, that Air or Vapour, whether lodged in the Caverns of the Earth, or detached from Fountains below, should administer a Supply of Water equal to what the least of the Rivers, we have before spoken of, can emit. Besides, it is not easy to give an Account how Liquors so distill'd, and in such a State of Rarefaction, should ascend through such Bodies (suppose them to be of Rock, Gravel, or Sand) as Springs proceed from.

As difficult (if not much more) is it to account how two such sudden Transmutations of Elements should immediately, and in so regular a Course, succeed each other, and be effected so perfectly, and in so little a Time; and how capacious and extensive those Receptacles must be, wherein that great Work is performed, may be guess'd at by what follows.

THE learned and most accurate *Robert Boyle*, somewhere says, That an Inch of Water rarified into Vapour (as it must be in Case of subterraneous Fires) is divided into 13300 Millions; and that one Drop of Water only is divisible into twenty-six Millions of Parts. This Rarification, and consequently Expansion, must, I say, take up so much Room for such a Change, that one should be very hard put to it to find where it is situated; and how so great a Work should be so justly effected as to keep the Streams of a River, or even a small Spring, in a constant Current and Supply.

IF there are any Things then as subterraneous Fires, (which by the Steam that arises in Cellars, and from hot Baths that reek so, there is some Indication there is,) the Use of them seems to be more probably this, *viz.* That it may rarify the Air in those Passages the better, and cause the Water by the Impulse of exterior Air, and other Fluids, to ascend the freer, as Heat does in the Pipes of a Fire Engine, where it is seen to mount to the greatest Height; but Water rarified into Vapour, would rather adhere and stick close to those Particles of Stone and earthy Matter through which they are to pass, than ever to ascend through them, which, in my humble Opinion, is a Consideration of no small Moment.

THE next Thing to be taken in Course, is to give the best Account I can, how it is that Water may be raised to so great a Height.

AND, 1st, That Water may be made to ascend above its proper Level by its own Inclination; 2dly, according to *Plott*, by the Help of Fire; 3dly, by Filtration; 4thly, by Attraction; and, 5thly, by the unequal Altitude of the Sea, which is proved by many Examples; 6thly, by the Help of the Distance of the Center of Gravity from the Center of Magnitude; and, lastly, by the additional Weight of the Atmosphere, Gravitation of the Moon in all high Tides, by the Help of Storms, Tempests, &c.

First of all, Tho' it be true that Water, according to the precise Laws of Hydrostaticks, will not rise higher than its Level, (if so high,) yet the Movement of ascending and descending Water in a Mountain is of another kind, as is seen in salt Sea-Water, which is more ponderous; and that of the Fountain, which is sweet and clear, and consequently lighter: Moreover, when the first presses downwards, and the later ascends in round Tubes, which still decrease till they are so diminish'd, as to turn into the finest Streams imaginable, such as Air, &c. and as Salt-Water is also always pressed by the immense Weight of Air; which spreading itself wide on its Surface, I can't see, (says my Industrious Author,) when all these Things are duly weighed, why it should not be believed, that the same Water should not be made to ascend higher than its first Level, even so long till it issues forth out of the Sides of Hills, in like Manner as Quicksilver is raised by the Air's Pressure on that subjected stagnated Mass, especially when it is not depress'd by any superincumbent Fluid, as is the Case in the open Air.

BUT, which is more to the Purpose: Another Reason why Fresh-Water, when stripp'd of its heterogeneous Parts, and made fine and supple, should ascend with Ease through the capillary Tubes or Fissures of the Earth by the collateral Pressure of complicated exterior Powers, which are always agitating and gravitating thereon, is its Fluidity; to which may be added, (what is just now hinted at,) that continual innate Heat, which, according to *Cartesius*, in his *Princip. Philosoph. Par. 4. Sec. 64.* and the Reverend Dr. *Shillingfleet*, then Dean of *St. Paul's*, in his *Origin. Sacer. Lib. iii. Cap. 4.* is always labouring in the Bowels of the Earth; a Process not disagreeable to what the ingenious Mr. *Hawkesbee*, (in his *Physico-Mechanical Experiments*, p. 144. *Exper. 5. &c.*) describes, when he gives an Account of the Ascent of Waters through a Tube filled with Ashes, (in the open Air, and in *Vacuo*,) there being naturally an innate Heat, which causes that Siccity, Drought, or Thirst, as is visible in Lime, and other calcined Bodies, which absorbs all Moisture to itself, and which, as this ingenious Gentle-

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46 *An Introduction to a General System*

man has very clearly demonstrated, is the Cause by which Water will rise through its Interstices, even beyond, and, I may say, in outward Appearance, without that adventitious Assistance which is deduced from the precise Laws of Hydrostatics, or the Equipondium or Balance of exterior Fluids, collaterally gravitating thereupon.

He took a Glass Tube thirty-two Inches long, tied a fine Piece of Cloth to the End, and filled it with Ashes sifted very fine, and as he put them into the Tube, ramm'd them down as close as possible. When the Tube was filled, a thin Bladder (which was freed from all included Air) was tied to the other End of the Tube, to receive the Air which should ascend through the Ashes as the Water rose: This done, the Tube was immerg'd into Water, and it was found that in the Space of sixteen Minutes, it had rose 1 Inch $\frac{1}{4}$; at the End of twenty-four Hours, (for the higher it went, the slower it rose,) it had risen only sixteen Inches, the Bladder at the Top being then near half filled with Air. An Accident then happened which did prevent any more Observations on the extending the Bladder; but the Water still rose higher, though slower than at first; and in twenty-four Hours more, it rose six Inches; again in twenty-four Hours, it rose four Inches and an half more; the succeeding twenty-four Hours, two Inches higher still; and being arrived within half an Inch of the Top of the Tube, that Space was filled in about ten Hours more.

MANY are the curious Observations that this ingenious Gentleman has made on this Experiment; but whatever was the Cause of the Ascent of that Water, it acted uniformly, since the Water in all its Parts was equally influenced by it; and had the Tube of Ashes been higher, the Water would undoubtedly have been raised through it. It may, indeed, be said that the Water in this Experiment was raised no higher than Mercury (which is of a more ponderous Nature than Water is) rises; but then it must be considered that the Rising of the Water in Ashes was through a Plenum; and the general Rise of all Water in open Air, through a real Vacuum, at least, a Vacuum disseminatum, (as the Learned term it,) nor will Water rise to thirty-two Foot high, so often mentioned, till the Air is sucked out by a Syringe-Pump, or some other Instrument; so that though this Rise of Water, may seem to owe its Motion to the received precise Laws of Hydrostatics, yet it is plain it did not, because the Experiment did not succeed better in Vacuo than in the open Air, though in a *Medium

*The Ascent of Water through Ashes in Vacuo is demonstrated in Exper. 6. Page 150. of the ingenious Gentleman beforementioned, who says he took a Tube about ten Inches in Length which

dium it did: On which Account it is pretty plain, that it had its Rise from the innate Heat, which laboured therein; which by its Collision against the more volatile fluid Flame, forced out the Air which was in the Ashes, in order to give Room for itself; and that without the adventitious Assistance, or Equilibrium of exterior Air; which is what I was in this Place to reason upon.

ANOTHER Method by which Water is raised in small Tubes, is *Filtration*. Now this Filtration is so well explained by the Ingenious Mr. *Hawksbee*, Page 28. of the aforementioned Treatise, that I shall make use of his own Words. "The Reason (says he) of raising the Water in a Filtre, will be manifest to him who takes Notice that a Filtre is constituted of a great Number of small long Bodies (the Interspaces of which may be called Capillary Tubes :) These Bodies lie so close together, that the Air in its getting in between, doth lose of the Pressure which it has against the Fluid which is without them; by which Means the Water or Liquor not finding so strong a Resistance between, as is able to counterbalance the Pressure on the Surface which is without, is raised upwards till it meets with such a Pressure as is able to hinder it."

As to the Rising of Oil, melted Wax, Tallow, Spirit of Wine, &c. in the Wick of a Candle or Lamp, it is evident, that it differs nothing from the former, save in this, that in a Filtre the Liquor runs away by another Part, and in the Wick the Liquor is dispersed and carried away by the Flame.

AND as for the Rising of Water in a Sponge, a Loaf of Bread, Cotton, or any such Substance, above the Superficies of the subjacent Liquor, (which the Reverend and Learned Mr. *Deerham*, in his Notes on his *Physico-Theology*, page 50. has hinted at,) what has been said of the Filtre, if duly considered, will easily suggest the Reason of it: For this voluntary Ascent, if I may so call it, (says the learned *Hooke*, Page 29. *Lib. prædic.*) it is, considering that all those Bodies abound with small Holes or Pores, that Water-Rises being all of them

with Ashes, (as before,) and placed it in a Reservoir, out of which the Air was exhausted, suffering it to continue in that State for some Time, to give Liberty for the Air which was in the Ashes to get away, then plunging the lower End of the Tube under Water, it was found (as expected) that the Water rose much faster in the rarified Medium, than in open Air. And this points out the Reason why the Water in the former Experiment rose faster at first, than when it had got up nearer towards the Top, viz. its being by its nearer Approach towards the Surface more sensible of the Resistance of the superincumbent Air; and this may be the Reason also why Springs don't always break out of the Tip-tops, but rather on the Sides of Hills.

them no unlikely Demonstrations of this Rise through the Veins and Pores of the Earth, as the Sap does through the Trunk of a Tree; especially if to it be added the unequal Altitude of the Sea, which will be proved from many Examples, when I have set down what the learned *Hooke* has suggested on this Head, namely, *That the unequal Height of the Surfaces of Water within, proceeds from the greater Pressure of other Fluids which are without*, that is, from their being of a more ponderous Nature, as Salt-Water is more ponderous than Fresh; and by that Means, even by the known Laws of Hydrostaticks, will raise the said Fresh Water higher than its own Surface, provided the Resistance of Air (which we have proved to be much lessened in this Case) be not too great.

THIS different Ascent of Liquors in Tubes of different Sizes, is visibly expressed in the Vessel G, Fig. III. Tab. seq. where the Tube C may represent Mercury, the Tube B another Liquid near of equal Weight to it, and the Tube A Vinegar, Fair Water, or any more subtil and thin Fluid, which are raised up to different Heights at E, D by the Gravitation of the Mercury in F.

FROM this it is that Doctor *Hooke* has drawn two Propositions; the first of which is, *That the unequal Pressure of incumbent Air* (or I add, any other Fluid) *will cause an unequal Height in the Waters Surfaces*, which proceed from thence.

AND the Second is, *That there is in this Experiment such an unequal Pressure.*

LET there be contrived such a Vessel, in which you can either increase or diminish the Pressure of the Air upon this or that Part of the Surface of the Water, the Equality of those Parts will be immediately lost; and that Part of the Superficies, which sustains the greater Pressure, will be inferior to that which undergoes the less. A Vessel fit for this Purpose, will be an inverted Glass Scyphon, such a one as is described in Figure IV. Tab. seq. For if you put Water enough to fill it as high as A, B, and gently blow in at D, you shall depress the Superficies B, and thereby raise the opposite Superficies A to a considerable Height, and by gently sucking, you may produce the quite contrary Effects.

NEXT, that there is such an unequal Pressure, I shall prove from this, That there is a much greater Incongruity of Air to Glass, and some other Bodies, than there is of Water to the same: But this particular Enquiry of Doctor *Hooke* is too long to be inserted in this Place; which makes me hasten to that which is of more Use in the Treatise I am upon, and which was one of the chief Corollaries drawn by that great Man, (*viz.*) Whether from the several Properties with which

Water and other Fluids were endowed with, (which are by him reduced to the general Laws of Motion and Rest,) the Rising and Ebullition of the Water out of Springs and Fountains, (which are generally esteemed to lie much higher than the Superficies of the Sea, from whence it seemed to be derived,) may not be explained by the Rising of Water in a smaller Pipe: For the Sea-Water being strained through the Pores or Crannies of the Earth, is, as it were, included in little Pipes, where the Pressure of the Air has not so great a Power to resist its first Rising: But examining this Way, says my learned Author, and finding in it several Difficulties almost unmovable, I thought upon a Way that would much more naturally and conceivably explain it.

I Took a Tube Glass of the Form of that described in the IVth Figure, Tab. seq. and chusing two heterogenous Fluids, such as Water and Oil, I poured in as much Water as filled up the Pipes as high as A, B; then putting in some Oil into the Tube A, C, I depressed the Superficies A of the Water to E, and B I raised to G, which was not so high perpendicularly as the Superficies of the Oil F, by the Space F I; wherefore the Proportion of the Gravity of those two Liquors was as G, H, to F, E.

THIS Experiment was also tried with several other Liquors, and particularly with Fresh Water and Salt, (which was made by dissolving Salt in warm Water;) which two, though they are nothing heterogenous or dissimilar one from another, yet before they could perfectly mix with one another, I made Trial of the Experiment: Nay, letting the Tube, wherein I tried the Experiment stand for many Days, I observed them not to mix; but the Superficies of the Fresh, was rather more than less elevated above the Salt-Water. Now the Proportion of the Gravity of Sea-Water, to that of the River, (according to *Stevinus* and *Varrennius*, and which has been since found by other very curious Experiments, is as 46 to 45. that is 46 Ounces of the Salt-Water, will take up no more Room than 45 of the Fresh; or reciprocally 45 Pints of Salt-Water, weighs as much as 46 of Fresh.

BUT the Proportion of Brine-Water to Fresh, I found to be near 13 to 12. Supposing, therefore, G, H, to represent the Sea, and F, I, the Summit of the Mountain above the Sea, F, M, a Cavern in the Earth, beginning at the Bottom of the Sea, and terminated at the Top of the Mountain; L, M, the Sand at the Bottom, through which the Water is, as it were, strained, so as that the Fresher Parts are only permitted to transfuse, and the Saline kept back: If, therefore, the Proportion to G, M, to F, M, be as 45 to 46, then may
H the

the Cylinder of Salt-Water G, M, make the Cylinder of Fresh-Water to rise as high as E, and to run over at N.

It is not much to the Purpose in this Place, to examine or confute the Opinion of those who affirm, that the Depth of the Sea is no more in Perpendicular than the Height of the Mountains above it, there being few, if any, that have experimentally known the Perpendicular of either: It is sufficient for the Purpose in hand, that the Gravity of Salt-Water is such, when compared with Fresh, that it will raise it higher than its first Level, and that agreeably to the so often repeated Laws of Hydrostaticks; which when added to what has been before set down concerning Filtration, subterraneous Heat, &c. will make the Ascent of Water to the Tops of high Mountains the less difficult and surprizing.

NOR is there Room here to determine, whether there may not be other Causes of the Separation of the Fresh-Water from the Salt; as that, perhaps, some Parts of the Earth through which it is to pass, may contain a Salt, that mixing and uniting with the Sea-Salt, may precipitate it, much after the same Manner as the alkazite and acid Salts mix with and precipitate each other in the Preparation of *Tartarum Vitriolatum*; neither can it be exactly known, whether the exceeding Cold, which must accordingly be at the Bottom of the Water, may not help towards this Separation, since 'tis found, that any Quantity of warm Water is able to dissolve and contain more Salt, than the same Quantity of cold; insomuch, that Brines strongly impregnated by Heat, do suffer much of their Salt to subside and chrysalize about the Bottom and Sides: Neither is it known, whether the exceeding Pressure of the Parts of Water one against another, may not keep the Salt from descending to the very Bottom, as finding little or no Room to insert it self between those Parts protruded so violently together; or else squeeze it upwards into the superior Part of the Sea, where it may more easily obtain Room for it self, amongst the Parts of Water, where there resides more Heat and less Pressure: To which Opinion some Geographical Writers seem to incline us, when they write of the drawing of Fresh-Water from the Bottom of the Sea, where it is naturally salt above.

BUT a Fifth Power, by which Water may be made to ascend to the Tops of high Hills, is by Attraction, a Principle (as the ingenious Mr. *Hawksbee* has it) which governs far and wide in Nature, and by which most of its Phenomena are explained; which Attraction has been attempted to be solved several Ways: Some attribute it to the *impeded or diminished Action of the Air*; others to the *In-nixion, or Resting of the Parts of the Fluid* on the Pores and Points

Points of Glass, or other Bodies, through which it passes; and others (of which the learned *Hook* in his *Micographia* just mentioned, is one) from the Congruity or Incongruity of the Parts of Matter one to another; all which being couched in hard and unintelligible Terms, which would rather confound than instruct my Reader, I can only say this, that 'tis plain there is such a Power in Nature, by which the Parts of Matter do tend to each other; and that not only in the larger Portions of it, but in those which are more minute and insensible.

To pass by then all the curious Definitions of the Attraction here spoken of, and which is one Cause of the Ascent of Liquids in small Tubes, and consequently of the Rise of Springs to the Tops of Hills, let A, B, C, D, Figure V. Tab. seq. be a small Tube perpendicularly immers'd in a Liquid whose Horizontal Surface is E, C, D, F.

THE Parts of the Liquid a, a, b, b, adjoining to the Concave Surface of the Tube, are strongly attracted by it, and that in a Direction perpendicular to the Sides of the cylinderick Glass; or (which is all one) parallel to E, F, the Surface of the Liquid.

NOW the Particles a, a, b, b, gravitating in Directions perpendicular to E, F, (that is, parallel to A, C, and B, D,) the Sides of the Tube: By Means of the Attraction it comes to pass, that the Particles a, a, b, b, have all of them a much less Momentum, or gravitating Force, than otherwise it would have, were the Attraction away. Therefore the Parts of the Fluid which lie immediately upon them, are much less pressed upon than otherwise they would be.

AND although the Particles d, d, lie farther off towards the Middle of the Tube, yet in a very minute and slender one, (such as is here mentioned,) they are near enough to be within the Reach of the powerful Attraction of the Surface, so far as to be in some Measure influenced thereby, either immediately or suddenly, by the Means of the Particles a, a, b, b, which are strongly urged towards the Glass, and do (by the general Law) attract the neighbouring Particles d, d, towards themselves.

UPON these Accounts, the Momenta of all those Particles, comprehended within the Circumference of the lower Basis of the Tube, being much lessened, the Fluid which lies directly under 'em, is proportionably less pressed.

BUT the Parts of the Fluid f, f, f, f, which lie between the Surface E, C, D, F, and the Bottom of the Tube are at more remote Distances from the Sides of the Tube, than its Semi-Diameter; these Particles, I say, being out of the Reach of any such Attraction, do

gravitate with their Force, or Momentum, on the Parts which lie under them: Therefore it appears, that by the Immersion of the small Tube into the Liquids, the Equilibrium is destroyed between those Parts of the Liquid lying within the Circumference of the lower Basis, and those that are without. And so by the Laws of Hydrostatics, the Liquid must rise within the Surface of the Tube; for the stronger Fluid (suppose Salt-Water or Fresh) will still press in upon the Weaker, and force it away before it, (as has been already demonstrated by Figure IV. Tab. seq.) that is, the Particles about a, a, b, b, principally, and next to them, the Particles about d, d, must necessarily give Way to the Particles below them, which are urged on by the superior Momentum of the Particles which come from the aforesaid remote Distances about f, f, f, f; from whence it follows, that those Particles about a, a, b, b, must necessarily ascend higher in the Tube, as to e, e, e, e.

WHEN they are risen higher, the Attraction to the Sides of the Tube will take place as before, and by lessening their Momenta, with respect to those below them, will give a new Occasion to the external Fluid, to insinuate it self within the Bottom of the little Tube, and consequently push those Particles still up higher as to g, g, g, g.

THUS by the continual Action of the same Cause, the same Effect follows, and the Liquor continues to ascend in the Tube, till it comes to a certain determinate Height, where it keeps its Station, and that by the same Laws which brought it thither.

AND this I take (with great Submission) to be a satisfactory Account of the Reason of this Phenomenon, and serves to shew the Manner and Way by which Liquids may be conceived to rise (not only) in small Tubes, and in Cases of a minute Nature, but also in those larger Bodies of Water, which rise through the Crannies and Pores of the Earth, &c.

AND having thus shewn the Methods by which Water may ascend by the Assistance of subterraneous Filtration, Attraction, or more properly speaking, by the Ascent of Liquors in the Capillary or small Tubes of Ashes in the open Air, and in Vacuo; it follows, that I endeavour to demonstrate that the Sea does lie as high, or higher in many Places, than the Land does; and that consequently the Laws of Hydrostatics have more Force in this great Work of Nature, than its Opposers, or those who are diffident of its Power, generally suppose it has, especially if to it be added the additional Gravitation and Pressures of the Moon and Atmosphere in Storms, High Tides, and turbulent Weather, &c.

THAT

THAT the Sea, and many large Rivers are higher in some Places, and at some certain Times, than the general Level of the Earth is, especially in high Tides, is not only probable, but very visible to any that shall duly and carefully consider it; and that it is near as high in meeting of the Tides in the Middle of the Ocean, as the general Run of Hills, is no less plain to those that have ever tryed it by Levels.

DOCTOR Plott, page 155. of his oft quoted *Treatise of Springs*, says, that the River *Trent* lies higher in the Counties of *Stafford*, *Darby*, *Nottingham*, and *Lincoln*, than the River *Dane*, *Don*, or *Dun*, which is in *Cheshire*, *Lincoln*, and *Yorkshire*, does; from which it is inferred, that the *Irish* lifts up its Head higher than that which we call the *Deucalidon Sea*: And according to the Authority of many ancient Mathematicians and Philosophers, (as *Cratotheres* by *Strabo* relates,) it is affirm'd, that at the City of *Corinth* the Sea was much higher than that of the *Saronichus* near *Cenchrea*, a Town of *Pelloponessus*, so that it frightened *Demetrius Poliocertes* (who otherwise was determined to have dug away the *Isthmus*) in such a Manner, that he left off his Design.

To the same Reason also (to wit, that of the *Ionian* being higher than the *Ægean Sea*) it was owing, that *Julius Cæsar*, *Caligula*, and *Nero*, having began, desisted from advancing that Work, as *Job. Bapt. Riccioli Geograph. & Hydograph. Reformatæ, Lib. I. cap. 16.* sets down.

ON this Account also it was, that *Sesostris* King of *Egypt*, *Darius* of *Persia*, *Ptolomy*, and after them (as *C. Plinius Secundus*, in his *Natural History, Lib. II. cap. 29.* likewise sets down) the *Ægyptian* Sultans, and last of all, the *Turkish* Emperors; and whoever was Prince in their respective Times, who had designed to attempt the Cutting through the *Arabian Isthmus*, which was between the *Red-Sea*, *Nile*, or *Mediterranean*. But having found by the *Ægyptian* Mathematicians that the *Red-Sea* was three Cubits higher than the Land of *Ægypt*, were afraid, lest that Country should be overflowed by a perpetual Deluge of Water.

NOR does this appear to be so amongst the Ancients, only since *Cabeus*, in his *Treatise of Meteors, Lib. I. Text 9. Question 9. and Text 73.* teaches, that it was manifest, even to common Sight, that the Gulph of *Geneva* is much higher than the *Adriatick Sea*; for if any one will take the Pains to ascend the Mountain of *Bochetta*, it is manifest (says he) by Inspection only, that the said Sea of *Geneva*, which directs its Course by *Serraval*, where it keeps to its Level, from thence to *Tartara*, where it is a kind of a flat or gentle declining Sea; and from thence to *Papia*, where its Declivity is greater;

er; till at last of all, it is still lower in the Gulph of *Venice*. And having so changed the Order of Nature, the Sea of *Geneva* is there lower than that of the *Adriatick*; though there are many which have affirmed the contrary.

Ricciolus (in his *Geograph. & Hydrograph. Lib. i. cap. 16.*) affirms, moreover, that he was informed by the Fathers of the Society of *Jesus*, that in the Mountains which are adjacent to the *Isthmus* of *Panama*, (from whence one may take a View both North and South of the *American* Sea,) it is manifest, that the Sea runs much higher at *Nombre-de-dios*, than it does at *Panama*.

FROM all which it appears, and this is the Reason, why the Bottom of some Seas are higher than others. Neither is this any new Thing, but such as has been long ago observed by *Aristotle* himself: For he affirms, not only that some Seas are higher than others, but that most Rivers flow from the West, because the Earth is there higher than in other Parts of the World, for which see his *Treatise of Meteorology, Lib. II. Cap. 1.*) From this Cause also it is, that *Fromondus*, as well as *Van Helmont*, confess, that the Tides which flow from the North to the South, run swifter than any where, although the Wind be against it: And so sanguine is *Helmont* in this Matter, that though he allows the terraqueous Globe is turned from the East to the West, and that it is spherical; yet for the same Reason he proceeds to deny, that its Figure is turned from North to South, but argues that it is there rather eclyptical, and not round, from the Observations of those who sail a good Way towards the North-Pole, who have asserted, that they ought to have seen the Sun sooner by a whole Month, if this united Body of Earth and Water was perfectly spherical; which Effect, as it greatly exceeds those Limits of Darkness, ought in all Reason, as it appears to me, to be from the greater Elevation of the northernly Regions, above those of the South. An Instance of this is Fact in the *Mediterranean* Sea, and in other Regions adjoining to it, as the aforesaid *Van Helmont*, in his *Ortus Medicinæ, Cap. xi. pag. 34, 35. Edit. Venetiis Anno 1651.* sets down: And how can it be otherwise, when the Northern flow into the *Atlantick*, or Western and the *Atlantick* into the *Mediterranean* Seas? Whereas the Current of the *Volga*, (if there be any subterraneous Correspondence of the *Caspian* with the *Euxine* Sea,) the *Danube*, *Tanais*, and *Boristhenes*, cause that all those Rivers which wander through such vast Tracts of Land from the North, and are carried in a continual Declivity all the Way, clearly to demonstrate, that the Place to which they go, is much lower than the Northern Plains from whence they proceed; the

he Seas whereof are lifted up so high, as that they may easily supply the Springs which are in the highest of the Southern Mountains.

BUT not to detain my Reader any longer in Pursuit of distant Enquiries, it may be proved from that Convexity which is in the Middle of the Sea itself, that at the Meeting of the Tides from the Shores from each Side, the Waters lie as high as most ordinary high Grounds where Springs break out do: Of this I have my self made Observations from the Point of *St. Katherine's*, and other Places in the Isle of *Wight*, which I shall by-and-by relate.

I KNOW that Monsieur *Robault* * in his *Phyicks*, ridicules the Notion of those who say, that the Sea lies higher than Land, and calls it a very absurd Notion; for then, says he, it must follow, *That Rivers do not decline, but run up Hill*. But when we consider the great Difference there is between high Water-Mark and the low, in some Places no less than ten, fifteen, or twenty Foot, and in others more, especially in high Tides and Fluxes of Water, 'tis not difficult to account for the easy Passage and Descent of Water at those Times, an Observation so common, that I need not enlarge upon it.

BUT that the Sea in general (at least the middle Part of it) lies rounder than the Land, is obvious in a great many Instances; especially in one Observation which I have (as is just now hinted at) made in the Isle of *Wight* some Years, and since much improved. The first Intimation which I had of it, was the Passage of a Ship out of those Coasts directly cross for those of *France*; where for some Leagues we could see the Ship very plain, but on continuing our View a great while, we at last discovered the Ship to disappear by Degrees; first the main Bulk, then the lower, and at last the Top Sails. And all this in a very little Time, not half an Hour, at most.

THIS occasioned another Observation, some Time afterwards in a pretty clear Day, and when the Water was near at its lowest Ebb, and about thirty Foot lower than the Eminence on which we stood; then by the Help of an indifferent Level, and indeed a worse Telescope, we found that the horizontal Line from the Place where we stood, was intercepted by the Surface of the Water; on which Account we moved up into more advanced Ground twenty or thirty Foot higher, and then we could just survey the highest Part of the Water; and upon advancing still higher, could by the Help of our Glasses, indifferent as they were, discover something like Land on the other Side, which

* Vid. *Robault's Phyicks*, Cap. X. Paragraph 4. Page 417. of *Dr. Clark's Edition*
 Quod Maris superficiis istis locis altior sit; quo nihil dici potest absurdius, sequeretur
 enim flumina non declivi, sed acclivi Cursu ad Mare reverti.

which we took to be the Coasts of *France*; which in very clear Weather, and with good Glasses, may be seen at any Time there. And what made it remarkable was, that on the other Side of the Hill, which was about two Miles Distance from the Place where those Observations were made, and as near as we could guess, (for we had not Time to make the Experiment,) the Springs cut at near that Level.

BUT if it be granted that the World is spherical, and that the Superficies of Water is spherical also, the Center of whose Sphere is the same with that of the Earth, (as *Archimedes*, in his two Books *de Insidentibus Humido*, which is rendered in *Latin* by the learned *Barrow* before nam'd, *Lib. I. Prop. 2.* asserts,) and that the Center of Gravity is but a very little Distance from the Center of Magnitude; Water is of so light a Nature, that if that which is in one Part be carried to another Part, which is a great Way off, into any Hill in that Part; the Water which is one, will so exsuperate the highest Hill which is in the other, *i. e.* that is far more distant from the Center of Gravity, than the Top of the highest Mountain can be; that I can't understand (says the learned *Plott*) what should hinder, why Water should not of its own Accord (contrary to all exterior Force, such as is demonstrable by the Laws of Hydrostatics) ascend to the Tip-top of the highest Mountain, that is any where extant in the World, when its Level is more elated, *i. e.* farther distant from the Center of Gravity, than the Top of the highest Mountain can be: And if we accurately consider the terraqueous Globe, we shall truly find the same unequal Difference of the Sea and Land, as there is betwixt the Center of Gravity and the Center of Magnitude; that it is necessary it should recede as much (though more might be said) as the Top of the *Mar de Zur*, or *Pacifique*, is distant from the Bottom. For that Sea, if you take it from the Shores of the River *Sinis*, you may suppose it to extend it self between the Longitude of 150 Degrees, and that of 160; from which you may collect, that it takes up one third Part of the Globe, and leaves the two other Parts of the Earth; so that if you suppose it affords so many, or such great Profundities, or Inequalities in the Bottom of this Sea, as are extant on the Mountains opposite to that Land, it will be very easy to understand how Water may be raised to the Top of any of those Mountains.

NEITHER can it be here objected, that if the Center of Gravity should be so far distant from the Center of Magnitude, but that it must necessarily happen it must drown a great Part of *Asia* and *America*, whilst it endeavours to keep to its Equilibrium, or Level; for the Shores of all those Seas being filled with Creeks or Rocks, which being, moreover, but a little higher than the Border or Bounds of
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of the Sea, although the Hill of Waters which is within appears to be gibbose, the Waters at the same Time rising to great Heights, (that should not God Almighty, in his due Time interpose, *who has set Bounds to the Waters, that they may not pass over, that they turn not again to cover the Earth; * And unto the Sea, he said, hither-to shalt thou go, but no farther; and here shall thy proud Waves be stopp'd, †*) those miserable Countries must of Necessity be drown'd.

AND if the Sea, consider'd in a State of Quietude, can do so much, how much more will it effect, when it is in a turbid or troublesome State, *When its Waters are gather'd together, as in an Heap; ‡ When the Lord shews his Wonders in the Deep, and raiseth up the stormy Wind, which lifteth up the Waves thereof, so that they mount up to Heaven, and then go down again to the Depths. §*

To all that has been said on this Head, namely, of the forcing of Waters through the subterraneous Ducts and Channels of the Earth, by the unequal Height and Pressures of Water in several Parts of the Ocean, &c. may be added, the Effects which proceed from the Flux and Reflux of the Sea, which is generally allow'd to proceed from the Gravitation of the Moon on the Atmosphere; such a Moon making such a Tide, being a common Expression amongst all Navigators: But whether her proper Action be to raise the Sea's Surface above, or depress it below its natural Level, seems not, perhaps, so easy to determine, since its Motion, alternately up and down, may be occasion'd by either, and is one undoubted Cause (amongst many others) by which Water is agitated, and forc'd to rise to the Tops of such high Hills.

THOSE who won't allow the Original of Springs to be from the Sea, own, as does the Learned *Nienwentyte, Sect. lxx.* of his *Religious Philosopher*, who says, "That the Waters of the Sea under the Moon, or nearly under it, do on both Sides of the Globe, raise an exceeding great and convex Mountain, which daily surround the Earth. Now that this can't happen without disturbing the Sea, *even in its deepest Cavities, is certain;*" and that Springs, which correspond therewith through the Veins and Fissures of the Earth, should not be affected also, is as much to be wonder'd at.

THE Antients generally attributed to the Moon a Power of raising or swelling the Surface of the Ocean, after the Manner of boiling Water; whence it was called the *Æstus*, or Ebullition of the Sea, which, as they held, was at once excited in the Parts directly under

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* Psal. civ. 9.
24, 25, 26.

† Job xxxviii. 11.

‡ Psal. xxxiii. 7.

§ Psal. cvii.

her Meridian, and those diametrically opposite to them; the former by her direct, this by her reflex'd Rays. Of this Opinion is *Aristotle*, in his *Treatise de Mundo*, *Cap. 4.* as also *Strabo*, *Pomponius Mela*, (as I find it in an antient Manuscript,) *Pliny*, (in his *Natural History*, *Lib. ii. Cap. 97.*) and others, who ascribe the Original of Springs to Air, Vapours, &c. And *Pliny* pleasantly calls the Moon *Sydus Avidum, trahensque secum Haustu Maria*, &c.

To proceed with a learned Author on this Subject. The Moon's Orbit being over those Parts of the terraqueous Globe which lie between the Tropicks, and where the largest Seas are, as she passes over them, presses those Particles of Matter which are underneath her, and they press the next under themselves, and so the whole intermediate Air; and thereby at last the Waters of the Sea, and so causes the said Water to rise on each Side of that Part of the Sea which lies under her Orbit, that is, towards the North and South Parts of the World. Hence to us, who live in the Northern Parts, the Tide always comes from the South, because the Moon's Orbit travels South of us: And on the like Account the Tide comes from the North, to those which live in the Southern Parts of the World, because the Moon's Orbit is North of them: And hence it is evident also, that the Tide must come so much sooner or later to any Place, as it lies more or less distant from the Tropicks, or that Tract of the Sea, which is underneath the Moon's Orbit.

THE Tide being thus caus'd by the Pressure of the Moon, it plainly follows, that because the Moon comes every Day to the Meridian of any Place fifty Minutes later than the Day before, therefore the Tide likewise must fall out fifty Minutes later every Day than the Day before, in respect of any particular Place.

ALSO the Moon is six Hours in coming from the Horizon of any Place to its Meridian, therefore it is obvious, that the Tide must be six Hours coming in; and in like Manner, because the Moon is six Hours in going from the Meridian to the Horizon of any Place, therefore the Tide must be the same Time in going out; where it is obvious, that as the Pressure of the Moon begins in respect of any particular Place so soon as she comes to its Horizon, so her Pressure continually increases, till she comes to the Meridian of that Place; and consequently the Tide still rises higher and higher, till she comes to the said Meridian; which, as the Moon leaves again, so her Pressure decreases; and consequently the Tide sinks lower and lower.

MOREOVER, it being agreeable to the Laws of Staticks, (as is found by Experiments,) for heavy Bodies to gravitate so much more as they come nearer to the Center of the Earth; hence the Reason why

why the Tides are bigger at the New and Full Moons, than at the Quarters, is easily assign'd, namely, the Moon's being at her Change and Full nearer to the Earth than at her Quarters.

AGAIN it is observ'd, that as the Tides at the Change and Full of the Moon are bigger than at any other Time of the Month, so the Tides at the Change and Full of the Moon about the Equinox, are bigger than those at any other Time of the Year; which may be accounted for by the Moon's being then over the middle Part of the Ocean, which is under the celestial Equator; and consequently, by its Pressure thereon, making a greater Quantity of Water to recede to each Side, *viz.* Northwards and Southwards, than when she presses on one Side of the Equator, and so not on the Middle of the Ocean.

It remains to be observ'd, that it is demonstrable by the Principles of Staticks, that the Moon does cause the Seas to swell, or, in one Word, the Tide not only in that Part of the Sea which she is over, but also in the Part opposite thereto. And hence it comes to pass, that there be two Tides every twenty five Hours, namely, because in that Time the Moon going from any Meridian, returns to it again; and consequently causes one Tide whilst she is in the upper Hemisphere, and another whilst she is in the lower Hemisphere.

BUT if we consider the Flowings of the Tide, and proceed to account for the Course of it, by the Rotation of the Earth, how greatly must such a Rotation contribute to the forcing Water through the Fissures and Chasms, or, in other Words, through the Veins and Arteries of the Earth?

AND here, before I end this Chapter, it will not be improper for me to take a View of what the learned and inquisitive Dr. *Woodward*, in his *Natural History of the Earth*, Part. iii. p. 131, &c. has set down, in relation to Springs; for though his Account be rather physical than mechanical, depending on the Doctrine of subterraneous or central Fires, yet, as he tells us, he had procured the Judgment of all those Persons on whose Fidelity he might rely, join'd to the Observations he had made himself. There is no Doubt, but his Enquiries are just in the main, though he may not account for the Ascent or Rise of Springs in the Manner they require.

IN the first Place he proves, " That there is a mighty Collection of
" Water in the Bowels of the Earth, constituting an huge Orb in the
" interior or central Parts of it, upon the Surface of which the terrestrial Strata are expanded; that this is the same which *Moses*, (and
" I add other Writers,) in Holy Writ, calls the great Deep, and the
" antient Poets *Erebus* and *Tartarus*.

60 *An Introduction to a General System*

“ *Secondly*, That the Water of this huge Orb communicates with
 “ that of the Ocean, by Means of certain Tubes or Chasins pas-
 “ sing betwixt it and the Bottom of the Ocean; that they have the
 “ same common Center, round which the Water of both of them is
 “ compil’d and arrang’d; but in such a Manner, that the ordinary
 “ Surface of that Orb is not level with that of the Ocean, nor at so
 “ great a Distance from the Center as that is, it being for the most
 “ part restrain’d and depress’d by the Strata of Earth lying upon it;
 “ but wherever those Strata are broken, or are so lax and poreous, that
 “ Water can pervade them, there the Water of the said Orb does
 “ ascend, filling up all the Fissures whereunto it can get Admission
 “ or Entrance, saturating all the Interstices and Pores of the Earth,
 “ Stone, or other Matter, all round the Globe, quite up to the Le-
 “ vel of the Surface of the Ocean.

“ *Thirdly*, That there is a perpetual and incessant Circulation of
 “ Water in the Atmosphere, arising from the Globe, in Form of Va-
 “ pour, and falling down again in Rain, Dew, Hail, and Snow;
 “ that the Quantity of Water thus rising and falling is equal, as
 “ much returning back in Rain, &c. to the whole terraqueous Globe, as
 “ was exhaled from it in Vapours; that though the Water thus ri-
 “ sing and falling, be certain and constant as to the whole, yet it va-
 “ ries in the several Parts of the Globe, by reason that the Vapours
 “ floating in the Atmosphere, sail in Clouds from Place to Place,
 “ and are not restored down again in a perpendicular Manner, upon
 “ the same precise Tract of Land, or Sea, or both together, from
 “ which they arose, but any other, indifferently; so that some Regi-
 “ ons receive more back in Rain, than they send up in Vapours; as,
 “ on the contrary, others send up more in Vapour, than they receive
 “ in Rain. Nay, the very same Region, at one and the same Season,
 “ sends up more in Vapours, than it receives in Rain; and at another,
 “ receives more Rain than it sends up in Vapours. But the Excesses
 “ of one Region and Season compensating the Defects of the others,
 “ the Quantity rising and falling upon the whole Globe is equal,
 “ however different it may be in the several Parts of it.

“ *Fourthly*, That the Rain which falls upon the Earth, partly
 “ runs off into Rivers, and thence into the Sea, and partly sinks down,
 “ (though not very deep,) into the Earth, insinuating it self into
 “ the Interstices of the Sand, Gravel, or other Matter of the exteri-
 “ or or uppermost Strata, whence some of it passes on, (I say,) into
 “ Land-Springs, Wells, and Grotoes, and stagnates there, till ’tis by
 “ Degrees exhaled again: Some of it glides into the perpendicular In-
 “ tervals of the solid Strata; where, if there be no Out-let or Passage

“ to

“ to the Surface, it stagnates as the other does; but if there be such
 “ Out-lets, 'tis by them refunded and sent forth, (as was more parti-
 “ cularly explain'd in the Account relating to Sir *Thomas Willough-*
 “ *by's* Coal Works in the last Chapter,) though but rarely with the
 “ ordinary Water of Springs and Rivers: And the rest, which, by
 “ reason of the Compactness of the terrestrial Matter underneath, can-
 “ not make its Way to Wells, the perpendicular Fissures, or the like
 “ Exits, only saturates the uppermost Strata, and in Time remounts
 “ up again in Vapour into the Atmosphere.

To all which he adds, and which I place by Way of Corolla-
 ry, *First*, “ That though Rains do thus fall into, and augment Springs
 “ and Rivers, yet neither the one nor the other do derive the Water
 “ which they ordinarily refund from Rains, notwithstanding what ve-
 “ ry many learned Men have believ'd.

“ *NOR Secondly*, That Springs and Rivers do not proceed from
 “ Vapours rais'd out of the Sea by the Sun, and born thence by
 “ Winds into Mountains, and there condens'd, as a modern ingenious
 “ Writer is of the Opinion.

“ *AND Thirdly*, That the before mentioned great subterraneous
 “ Magazine, (with its Partner the Ocean,) is the standing Fund and
 “ Promptuary which supplies Water to the Surface of the Earth, as
 “ well Springs and Rivers, as Vapours and Rain.

“ *Lastly*, He proceeds to assert, That there is a nearly uniform and
 “ constant Fire or Heat, disseminated through the whole Body of
 “ Earth, and especially the interior Parts of it. But this Account is
 “ so interwoven with physical Ideas, that it will be too tedious to in-
 “ sert in this Place; nor can I (I must confess) rightly understand
 “ it, though *Descartes*, *Robault*, and others, maintain it with great
 “ Resolution.”

BUT before we draw to a Conclusion of this long and laborious
 Enquiry into a Part of Nature so useful and beneficial to Mankind,
 as this is, it will not be improper to take a short Survey of what Au-
 thors have said of that Deluge, with which the World was so re-
 markably destroy'd, and from whence it was suppos'd that those
 Waters were deriv'd: And here I think, the Contenders for the Hy-
 potheses, that Rain, &c. was the only Cause of it, are at a great
 Loss.

THE general Account that we find of it in Sacred Writ, is taken
 from *Genesis*, Cap. vii. 11. *That in the six hundredth Year of Noah's*
Life, in the second Month, the seventeenth Day of the Month, the
same Day, were all the Fountains of the great Deep (though the
 Main-

Maintainers of Rain allow us none) *broken up, and the Windows of Heaven were open'd.*

FROM whence several Conjectures have arisen; some imagining, that a Quantity of * Water sufficient to make such a Deluge, was created upon that Occasion; and when the Business was done, all disbanded again, and annihilated. Others suppose a Conversion of Air and Atmosphere into Water, to serve the Turn. Many of them were for fetching down I know not what super-celestial Waters for that Purpose. And *Descartes* merrily enough, and wide enough from the Principles of Reason, fancied (in his *Princ. Philos. Lib. iv.*) that the World at that Time fell all to Pieces, and so contracting itself (a strange Way of arguing) into a lesser Room than it originally had, was the Reason that a less Quantity of Water might surround and encompass it, with more to the same Purpose, all equally wide of Truth, and the Mind of the Sacred Writer.

THE ingenious Mr. Ray, in his *Treatise of the Dissolution of the World*, says, p. 99. "That this Deluge was from the Centers of the
" Earth being chang'd, and set nearer to the Center or Middle of
" our Continent; whereupon the *Atlantick* and *Pacifique* Oceans must
" needs press upon the subterraneous Abyss, and so, by Mediation
" thereof, force the Water upwards, and at last compel it to run
" out at those wide Mouths and Apertures made by the divine Power
" in breaking up the Fountains of the Deep." Which, by-the-by, is a Confession that there were such Passages then made and form'd; and why they should not continue ever since, we are not told. And to proceed to our curious Author, (though he argued much for the Derivation of Springs from Rain, yet he was without any great Concern for the Success of his Hypothesis, as he himself tells us, p. 101.) And in the Page before that says, "That the divine Power
" might at that Time, by the Instrumentality, of some natural Agent
" to us at present unknown, so depress the Surface of the Ocean, as
" to force the Waters of the Abyss through the forementioned Channels and Apertures, and so make them a partial and concurrent
" Cause of the Deluge." And he agrees further, "That there are sometimes in the Course of Nature, extraordinary Pressures upon the
" Surface of the Sea, which force the Water outwards upon the
" Shores to a great Height;" which is (I think) as good as granting what we have been long explaining, I mean, as to the Correspondence and Ascent of Water from subterraneous Causes.

Dr.

* For the Illustration of this, see Part iii. p. 176. of Mr. Woodward's *Natural History of the Earth*.

Dr. Burnet, in his *Theory of the Earth*, Lib. i. Cap. 2. considering how unsuccessful the Attempts of those who were gone before him had prov'd, and having himself also employ'd his last and utmost Endeavours to find out Water for the vulgar Deluge, he prepares for a Surrender, and says, "That to find out Water sufficient for this Effect, as it is generally understood and explain'd, is impossible." Not considering, that besides the Rains which then fell, when the Windows of Heaven were open'd, that the great Abyss also surrender'd its Water; and though it might rise fifteen Cubits high above the Surface of the Earth, as by common Tradition it is suppos'd to do, yet that there might be Water enough for such a Purpose, is evident enough. Nor does it follow, (if there were so many Hills as there are now,) but that the Water might gush out there, and drown all the lower Valleys, (to which Places the Inhabitants of all Ages have repair'd, that they might live out of the Winds that reign'd above:) I say, such a Deluge is not inconsistent to this Rise of Water, which I have been all along explaining, but rather makes much for it: And that those Vents, and such a Communication and Correspondence as I have been all along maintaining, might have their Enlargements, if not first Rise from thence, is not improbable to suppose.

FROM all which, and a thousand more Reasons that might be produc'd, it is evident, that all perennial Springs may, and do derive their Source from the Sea and subterraneous Causes, &c.

C H A P. IV.

Of irregular Springs; and the Method by which they are transmitted to the Surface of the Earth, lose their saline Properties.

HITHERTO we have discours'd only on those Springs which are regular and perennial, or, in other Words, those which flow in a regular Manner, and without any Intermiſſion: But there are other Queries to be answer'd in the Phænomenon of Springs, which naturally fall in this Place, namely, How it comes to pass, that there are sometimes Salt Springs, which lie much higher than the Superficies of the Sea itself? and then, How it comes to pass that Springs do not run faster and flower, according to the different Height of

64 *An Introduction to a General System*

of the Cylinder of Sea-Water, by the Ebbing and Flowing of the Sea?

As to the first, it may be answered, in short, that the Fresh-Water may receive again a saline Tincture near the Superficies of the Earth, by passing through some Salt Mines, or else many of the saline Particles of the Sea may be kept back, though not all. And as to the second, Why Springs do not run faster and flower, according to the varying Height of the Cylinder of Sea-Water, by the Ebbing and Flowing of the Sea? since the Water is lowest in many Springs and Ponds, at the same Time it is highest in the Sea or River; and the Water is highest or most flowing in the Spring or Pond? at the Time of Low-Water in the Sea or River; as also why the Water of many Pools or Brooks are highest in the dry Summer, and lowest in the Winter rainy Seasons? these and some other irregular Productions of Springs, I now come to consider of:

THE first is one found by Dr. *Plott* himself in the Parish of *Whittington* in the County of *Stafford*, near a Place, called by the Name of *Hangermore-Slade*, which, as this learned Author relates, (*p.* 14. of his *Treatise de Origine Fontium*), and which was the common Report of that Country, never flow'd but upon the Approach of some Scarcity of Corn; but at other moist Seasons, when it might, or ought to abound, it was entirely destitute of Water; such was the Year 1680. though there had been near a whole Month's Rain before the Time he observ'd it. But when it did break out, (which was sometimes scarce once in an Age,) it scarce flow'd above thirty Perches; but forthwith it disappear'd again, and was suck'd up and lost in some sandy Ground.

THE same Thing happens in a Place, call'd *Ashwood*, in the Parish of *King's-Swinford*, near *Swindon* in the same County, which flows not (according to common Tradition) unless there is like to be a subsequent Penury of Corn; but when it does flow, it is with as great a Noise, as the rattling and clashing of Iron; and so terrible was the Sound thereof, that they report some Thieves that harbour'd thereabouts being struck, as it were, with the Terror of a guilty Conscience, immediately ran away. Not unlike to this is a Well in the Peak of *Derby*, call'd *Weeding-Well*, which, as the ingenious *Cotton*, in his *Wonders of the Peak*, *p.* 26. tells us, bellow'd out a hoarse Sound, which it does at such uncertain Periods of Time, that it is difficult to assign the Day, much less the Hour of its Fluxion. Of the Method of its Flowing, the acute *Hobbes* of *Malmsbury*, who was, I think, Tutor to the then Marquis of *Hartington*, afterwards

terwards Duke of *Devonshire*,) has given an Account in his Poem on the Wonders of the *Peak*.

*Fons hic temporibus non tollitur (ut mare) certis
Æstibus his nullam præfigit Ephemeris horam.*

THIS was a Specimen of *Hobbs's* Averſion to the ſaid Wells, owing its Affluence to the Sea; but the ingenious *Cotton* ſoon retorts it back again,

*Fertur in arva ruens hic ſemper limpidus Amnis,
Et punis, nunquam pluviis hyemalibus Auctus.*

De Mirab. Pecci. Pag. 29.

BUT not to detain my Reader too long with Things of ſo little Moment, the famous horary Fountain of *Lufus* in *France*, (as related by *Emanuel Maignan*, in his *Perspective of Tholouſe in Gallia Narbonenſis*, Lib. i. Prop. 1. Sec. 3.) exactly increaſes itſelf by little and little, yet not without the Noiſe of mighty ruſhing Waters; and by-and-by flows out into a large River; and then by the ſame Degrees it roſe ſubſides again; and at laſt grows quiet, and quite dry. This, *Du Bartas* ſays, continues four Months; but *Gaſſendus* ſays, only three; and that it breaks forth only in *May*, *June*, and *July*.

NATURAL Hiſtories produce an infinite Number of theſe irregular Springs; but that which *Pliny Junior*, Lib. 4. Epist. ult. relates to be in *Agro Comenſi*, as he calls it, the Country of *Coma* in *France*, which is three Days in its Increaſe and Decrease, and *Gaſſendus*, in his *Phyſicks*, Lib. iii. cap. 7. ſays, that the *Niger*, a River of *Africa*, and the *Ganges*, increaſe and decreaſe in certain ſtated Seaſons; and the ſame *Gaſſendus* mentions a Spring in *Colle Martienſe*, as he calls it, which flows and reflows eight Times in every Hour. The ſame Thing happens likewise by the ſmall Village of *Kilken* in *Flintſhire*, who, as the learned *Therret* in his *Prin. ver. Nat.* Pag. 222. flows and reflows reciprocally every four Hours: To this may be added what is ſaid of the great River *Nile*, which begins to decreaſe about the 24th of *September*, and ſenſibly diminifhes till the Beginning of *May* following; when it becomes ſo languid and ſo little, that it ſeems rather to be ſtagnate, than to flow at all. But in *June* and *July* it begins to increaſe again, and ſo goes on till about the 17th of *September*, according to their (but the 24th of the

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ſame

same Month, according to our) Calculation ; at which Time those Inundations happen, with which *Ægypt* is so wonderfully enriched.

A FULL and particular Account of this *Nile*, and other Rivers, we have from *Varennius*, *Lib. i. Prop. xx. Page 249.* with which other Authors also agree, which beginning its Inundations about the 17th of *June*, and increase forty Days ; and the same Time again in its Decrease, covering every Thing but the Hills ; at which Time the Cities which are built thereon look like so many Islands. And all this, by the By, happens, tho' there are few or no Rains which fall in all that Country.

I SHALL not trouble my Reader with the Account which *Seneca*, who, from the Opinions of the *Greek* Physicians, wrote a learned Treatise concerning Springs, none of which, as *Varrennius* observes, is true ; because in those Times no Body went out of *Europe* to those Fountains, because they were very remote from *Egypt* ; but lately (as says *Varrennius*) the Cause of those Inundations are explained, and the true Cause found out by the *Portuguese*, *Dutch*, and *English*, which hold Commerce in the Kingdoms of *Congo*, *Angola*, *Moromotapa*, &c. and by them it is known, that the Fountains from which the *Nile* proceeds, is the great Lake *Zair*, situate on the Borders of *Africa*, between the eastern and western Shore, under the 10th Degree from the Equator, Southward.

ADJOINING to this Lake there are many Ridges of Mountains, which, from their Circularity, are called *Lunæ Montes*, or Mountains of the Moon ; and one Ridge they call *Seth* ; in the Middle of which Mountains lies this Lake : But because these Mountains are turned southerly from the Equator, it is Winter with them when it is Summer with us ; but being but a little Way distant from the Equator, they perceive no Cold, but have Rain in the room of Snow constantly two Hours in a Day, before and after Noon, in the Kingdom of *Congo*, &c. and in the Mountains which join to those Kingdoms, it rains almost continually at that Time of Year, that the Ridges of those Mountains look as if they reached the Clouds ; from which the Rains running down in great Torrents, flow altogether into the Lake *Zair* ; and from thence (but by what Passages *Varennius* does not tell us) into the Current of the *Nile*, that the *Cuama*, and other Rivers which flow out of this Lake, overflows likewise, but not in so great Plenty : The *Zair* nevertheless flows every Year at these Seasons, as the *Nile* does. And from hence is the manifest Cause of the Inundation of the *Nile*, (to wit,) to that great Plenty of Water, which fall from those Hills ; the chief Occasion of which is owing to the continual Rains that fall on the
aforementioned

aforementioned Hills, and from thence run down into that Lake; which Rains happen about the Middle of *March* or *April*, because from the 4th of *March* to the 21st, it is Autumn with them, and then these Rains begin; but they are less vehement in *May*, *June*, and *July*, than before; in *August* and *September* they are still less, and in *September* they cease quite.

BUT let not the Maintainers of Rain and Vapours from hence argue, that the Inundation before mentioned, is wholly to be ascribed to their Hypothesis: Those who are on the other Side of the Question always allow, that the Rains which are supped up by the Sun fall on high Hills, and then run down precipitately into Valleys and Rivers, and from thence into the Sea; by which Circulation it is that the Sea is undoubtedly maintain'd; but then they deny, (and that with great Reason,) that these Rains sink into the Crevices of the Ground, and constitute Springs.

To this Account of the *Nile*, may be added those which flow out of the Lake *Chiurny* into the Bay of *Bengal*, and passing through the Kingdoms of *Pegu*, *Siam*, and other Places, flows through the Country of *Siamensis*, called *Menan*. This Inundation happens in *September*, *October*, and *November*; at which Time the Fields are cover'd with Water, &c. Another is called the *Silver River*, in *Brazil*, which flows at the same Time that the *Nile* does.

ANOTHER is the River *Macon* in *Gamboice*, which overflows in the Summer Months. Another is the River *Parana*, or *Paranguasa*, which flows in the same Manner as the *Nile* and the *Silver River* in *Brasil* does; on which Account some will have it to be the very *Silver River* itself.

OTHERS there are, as the *Euphrates*, which, at certain stated Seasons of the Year, overflows *Mesopotamia*; and another River there is in *Numidia*, called *Sus*, which overflows in the Winter; and all these owe their Fluctuations to one Cause, (to wit,) to the Abundance of Rains, Snows, that then fall, and run into these Lakes, or Sea. To avoid Prolixity, the River * *Bibara*, near *Paris* in *France*, swells to that Degree, sometimes without any Rains, at least not those which are extraordinary and unusual, (to be sure by high Tides, as about *London*, and other Places it does,) that it lays waste the adjacent Suburbs of *S. Marcellus*. All which I give in *Varen-*
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nius's

*Fluvius Bibara in Franciâ prope Lutetiam, aliquando sine ullis Pluviis, aut certe non inusitatis, sic intumescit ut adjectente suburbio S. Marcelli inferat magnam vastitatem. Vid. Varenn. Geograph. General. Lib. i. Prop. xx. Pag. 260.

68 *An Introduction to a General System*

rennius's own Words, because the River he has mentioned is not to be found in any of my Dictionaries.

BUT to shew that we need not go so far for Examples of this Kind, there are Springs of our own, (as the learned *Cambden*, and after him *Speed*, relates,) which observe an irregular Motion; one whereof is a Well upon the River *Agmore* in *Glamorganshire*, and near unto *Newton*, which ebbs and flows quite contrary to the Motion of the Sea, being almost empty at Full-Sea, but full at Low-Water; which may come, as that curious Observer Dr. *Hooke* observes, *Page 27.* of *Micographica*, tells us, from the Bottom of a Sea very remote from those Parts, and where the Tides are much differing from those of the approximate Shores.

BUT to proceed: Another Example of the Irregularity of Springs is found near the River *Loder*, or *Lowther*, in *Westmoreland*, which ebbs and flows many Times in a Day: This likewise, says Dr. *Hooke*, may proceed from its being supply'd by many Channels coming from several Parts of the Sea, lying sufficiently distant asunder, to have the Times of High-Water differing enough from one another; so as that whensoever it shall be High-Water over any of those Places where these Channels begin, it shall likewise be so in the Well. All Regularities, as well as Irregularities in the Fluction of Springs, may (as I said before) proceed from divers Ducts coming from very distant Parts of the Sea, so as that it may be in one Place High, in another Low-Water; and so, by that Means, the Spring may be equally supply'd at all Times; or else those Ducts may be so strait or narrow, that the Water not having so ready and free a Passage through it, cannot, upon so short and quick a Mutation of Pressure, be able to produce any sensible Effects at such a Distance.

BUT the best Account that has yet been given of this Irregularity of Springs, is that which the learned *Desaguliers*, in the *Transactions* of the *Royal Society* for *July*, *August*, and *September*, *Anno 1724.* *Numb. 384.* has given concerning the *Lambourne* Spring, which is in the County of *Berks*, and another at or near *Greenhive* in the County of *Kent*; the first of which, as Dr. *Plott*, in his Treatise *de Origine Fontium*, *Page 41.* says, was communicated to him by *John Hippesty Esq;* a Neighbour in that Place, which flows more plentifully in the Summer than in the Winter; and which was more considerable, that in the memorable Drought, which happened in the Year 1681. when other Rivers were almost dried up, these Springs and Rivulets were higher than even they used to be at that Time of the Year; nor did they, till about the Middle

dle of *September* (the usual Time of their Abatement) fail: When, nevertheless, a great Quantity of Rain had fallen before that Time, yet there could not be found so much as a Drop of Water in the Bowels of the Earth thereabouts, till towards the Middle of *February*: At that Time the Springs began to flow again as usual.

BUT to proceed with our learned and curious Hydrostatician, he tells us, that *Hero Alexandrinus*, and other Hydraulick Writers, have described a Cup, (called a *Tantalus* from its Effects,) which will hold any Liquor very well when it is not filled above a certain Height marked in the Cup, which is performed by a Syphon concealed therein to make the Effect the more surprizing.

THE Cup A B, Fig. 6. Tab. seq. has a visible Syphon C E D in it, the Cup Fig. 7. has its Syphon more concealed, as it is carried up into the Handle; but in that of Fig. VIII. in which is the Figure of a Man, representing *Tantalus* in the Fable, who was up to the Chin in Water yet could not drink; where the whole Syphon (tho' now laid open by the Section) might be concealed. Any of those Cups, says our Author, will hold Water very well, provided they are not filled above the Line F G; for then not only the Liquor, which is above F G, will run out, but all the Liquor in the Cup as low as D, the Orifice of the short Leg of the Syphon.

To explain this, that ingenious Gentleman has produced an Experiment, Fig. 9. ead. Tab. wherein the Vessel a b c d is placed an open wooden Box, A B C D, filled with Water as high as the Line L M; another Box or Plug, E F G H, made tight, and containing Weight to sink it, is made to let down into the Water between the Partition I K, and the End A B of the Box above mentioned; but when it is not to press the Water up to I, (as it does when let down,) it is drawn out of the Water by the Weight M, which pulls it up by the Bar i k, fastened to a Leaver, moving round the Center L.

WHEN, by Means of the Plug the Water in the Space A B K I, is pushed up to I O, by passing under K, it runs out through the Spout P Q, (whose Passage is gauged by a little Sluice P p,) and falls into the Vessel R S, made of an oblong Figure, like a Fish-Pond, and having a Scyphon at S, so as to make it a *Tantalus*, or in the Nature of the Cups above mentioned.

LET the Weight M pull up the Plug E F G H, and the Water having filled R S, will run down below the Orifice P to m.

THE *Tantalus* R S, beginning to run out as soon as full, will, for the Reasons above given, continue to run out till it is all emptied; and as it discharges itself into another *Tantalus* T V, whose Scyphon is

is at V. this last *Tantalus*, will also, when full, begin to run out, and its Water go down to x Y o.

IF the Plug be let gradually down, as soon as the Water begins to run out of the last *Tantalus* T V, (and the first *Tantalus* R P be covered so as to be concealed from Sight,) it will appear to the Lookers-on, that the Cavity T V, representing a Pond near an ebbing and flowing River, as there is credible Information there is one at *Greenhive* in *Kent*, between *London* and *Gravesend*, always rises whilst the Water at N O (or the Tide) falls to L M; and always sinks whilst the Water at L M, or the Tide rises at O L.

THIS has also been the Occasion of another Experiment, (Fig. ix.) which let it be the Water in the Box, A B C D, not made use of, only the Vessel Z be filled every half Hour, it will empty itself in the Space of a Quarter of an Hour, falling like Rain, and dropping also through the Leaden Platform e f into the hidden *Tantalus* R S, which will not begin to run till this artificial Rain is over: Then in a Quarter of an Hour more the *Tantalus* R S will have emptied itself into the visible *Tantalus* T V, which will be filling all the Time after Z has done running, or in the dry Season,) and as soon as T V is full, it will begin to run through its Syphon V, at the End of the half Hour, when the Vessel Z, or Seive, runs again, that is, at the Return of the Rainy Season.

AND this last Experiment may be easily apply'd to those Ponds, or those Brooks, that are high in dry Weather, and low in wet; of which Kind there is one at *Lambourn* in *Berkshire*, as there is credible Information; but this, I must own, I have not seen.

IF it be objected, that such Ponds are full for some Time, which a *Tantalus* cannot be, because it begins to run out as soon as full; that may be easily solved, by supposing the hidden *Tantalus* (or intermediate Cavity between the River and Pond,) to contain more Water than the visible one, provided it does not contain so much as not to be emptied before the Return of the Tide.

THE same Solution will serve for wet and dry Seasons, only supposing the Cavities larger.

If it be asked where the Water of the visible *Tantalus* near a River can run; it may be answered, That all this may happen, tho' the second or lowest *Tantalus* should have its Bottom higher than the Low-Water Mark in the River. And for the Syphons which are of a particular Make in the Cup, though such be not supposed in the Earth, yet any long Passage rising in the Middle will answer the End. (See Fig. x.) where A B C D represents the Channel of a River, A D the High Water, and G H the

the Low-Water Mark, Z I a Passage from the River to the Cavity I K L M N, or first or hidden *Tantalus*, L M Q, the Scyphon of the first *Tantalus*, running into the second, or visible Pond O Q R P, which by its Syphon R S V, runs out into low Grounds that may be above the Low-Water Mark G H, and the Bottom K L of the first *Tantalus* may be above the Top of the last, whose Level is the Line W W.

A B C D Y O Q R P V H is the Section of the Surface of the Earth.

THE Irregularity of Springs being thus accounted for, it may not be improper in the next Place to answer some few Objections which have been brought against the Opinion of those who hold their Original from the Sea, I mean, as to their parting so easily with those saline Particles with which by Nature they abound.

THOSE who argue against the Derivation of Springs from the Sea, and would ascribe it to Rains, Vapours, &c. are very easily persuaded to believe how that Separation is effected in the sublimer Regions of the Air, in which they agree, that Sea-Water, exhaled by the Power of the Sun, is in its Sublimation stripped of all its saline Particles, not only fixed, but volatile, before it can or does descend again in Rain; but when they are, I say, made to believe how easy this is effected, (*in sublimoribus*,) if I may use the Words of a learned Physician on this Head, how comes it to pass that they can't conceive how Nature, who is regular and uniform in all her Proceedings, should not effect the same below, as she does above?

BESIDES all, it is, indeed, much more easy to account for the Methods by which it is done within, than without the Surface of the Earth, not only by Percolation, but by Evaporation. Also as *Aristotle*, with whom our learned Countryman *Lydiat*, in his *Disquisit. Physiolog. de Origine Fontium*, Cap. 2. *in initio*, agrees; it being an absurd Thought, that the same Effect can't be produced in the obscure Passages of the Earth, as is in the open Spaces of the Heavens, (to wit,) by that innate Heat which labours in the Bowels, and causes a Reak in the coldest Winter Months, and acts, perhaps, in a much more regular and uniform Manner than the Sun does, especially in Winter, when Sublimations are more rare, and Rains most certain: For the effecting of which, as they can render no particular Method, why should they, by Parity of Reason, expect the same from us?

BUT if we consider the almost innumerable Degrees of Percolation and Evaporation, which Water undergoes in its Passage through the Body and Pores of the Earth, in four or five, or, perhaps, six or seven Thousand Miles running, how many of its gross Humours must
natural-

naturally subside, and be strained off in the Ducts and Tubes of the Earth? how gently the whole Mass must be rarified by that subterraneous Heat? which is so visible in all new-dug (as well as old) Cellars and Vaults, and evaporated and carried off in Lakes, and open Bodies of Water, so great, indeed, that a rational Man ought not to wonder how Sea-Water shall be thus stripped of its pristine Humour.

To answer another Objection often made use of, namely, how comes it to pass, that those subterraneous Ducts, through which the aforesaid Percolations are made, (if Salt be endued with such an adherent Quality,) are not filled up with those great Quantities of Matter, which must naturally subside, or adhere thereto; since the Beginning of Things, and long ago filled up, and quite obstructed.

To this may be answered, in a few Words, That it is in the first Place as probable that the saline Particles here understood are entirely excluded those Tubes and Meanders, it having been before noted, that even the Bottom of Sea-Water, is much sweeter than that at Top; as that it is certain in the next Place, that the Pores and Channels of the Earth, may be dilated and extended thereby; Sailors knowing, from sad Experience, in a Scarcity of Fresh, when they are obliged to filtre their Salt-Water through a Vessel full of Sand or Earth, by which Means it will be at first a little sweeter; yet having repeated those Strainings often, the Pores of the Earth will be so relaxed, that very little more of that pristine Unpleasantness will stick thereto. From whence it is certain, that those Meanders, which have been in the Ground since the Beginning of Things, grow larger and larger, rather than fill up. And that those Humours not being of a terrene Substance, either evaporate by Heat, or, by Way of Sudation, separate themselves from that which is Fresh, and perspire into that muscular spungy Substance with which the Earth is composed, still leaving the main Arteries and Veins thereof open and at full Liberty, for that Conveyance and Ascent of Water which we have been so long discoursing of.

AND this is the Reason that Springs (as the Right Reverend and Learned *Stillingfleet*, in his *Origin. Sacr. Lib. iii. Cap. 4.* rightly observes) are not every where, and without Distinction found; but only every where in its proper Channels, as the Blood in the Vessels of Animals: For if you squeeze those Animals in those Parts, they will immediately emit Blood from thence; but if the Lancet happens amongst the muscular or more callous Parts of the Body, where no Blood is apt to follow such an Incision, except it be made higher, or in another Place.

IN like Manner you may dig to an incredible Depth in some Places, before you can fall upon Water; and in another Place, scarce a Stone's-throw from the former, you may find it plentiful enough, and that not far from the Superficies of the Earth. Of this many Examples might be produced, but especially one, which our often quoted laborious Author *Plott*, in his natural History of *Staffordshire*, mentions to be at *Barlaston*, near *Newcastle upon Tine*; where it is remarkable, that in the South Isle of the Church, as often as they have Occasion to dig any Grave, the same is immediately filled with Water, though it is covered from all the Rains which fall from above; but if you dig in any other Part of the Church, or in the Church-yard adjoining, it is there perfectly dry. And even so much farther remarkable was it, that a Gentleman of the *Bagnal* Family assured our Author, that he had a Well not far distant from thence, at least sixty six Foot deep, which afforded but little Water in the Winter, and scarce any in the Summer.

BUT there is in that County, says the same Author, another Instance that more plainly demonstrates the Derivation of Fountain-Water through the Channels and Ducts of the Earth, (ascending up therein as the Blood does in the Veins of Animals,) than any yet mentioned; and which the most sagacious and learned Gentleman, *Walter Chetwynd*, of *Ingestre*, Esquire, often related to him; that at what Time soever my Lord *Aston* cleansed the Ditches, which were in the Meadows in the subjected Plain between the River and the Town, which he used sometimes to do, he plainly drew off the intercepted Water by that Means; which could not in the least happen, unless the Water which run through such Ducts and Channels directly from the *Sovo*, (for so he calls the River, I suppose, there running,) and was to be carried up into the Town.

AND now we have a little expatiated on what was in the Beginning of this Treatise of Springs hinted at, I mean the Analogy that naturally occurs between the Macrocosme and Microcosme; it may not be amiss to draw a short Parallel of the Methods by which this great Work in Nature is effected.

I IMAGINE then that the Sea (which is subject to the Laws of Gravitation, and the Pressure of the Moon and Atmosphere thereon, as has been before demonstrated) is the Fund from whence all Springs originally proceed. Now as the Blood, which proceeds from the Body by the Compression and Dilation of the Heart, (being the Seat from which Life itself has its Existence,) distributes itself through all the Ducts and Veins of the Body, in a due and regular Circulation; so does the Sea by the Gravitation and Compression

sion of the aforementioned Powers, force on the Water through all the Chasms and Ducts of the Earth, receiving it again, being hastened in its Journey, and incorporated with and rarified by the Spirits and subterraneous Effluvia it meets with in its long Passage through it; and this Circulation and Ascent of Water through the Veins and Ducts of the Earth, can't in the least be wonder'd at, when we consider the Excellence and Power of that great Architect who first framed the World, and all that is therein.

If we take a farther View of this Ascent of Springs, and compare them to the Ascent of Sap in Trees, which does not, indeed, according to the new Hypothesis, circulate, but ascend as the Water does in an artificial Syphon, perhaps, by the Laws of Rarefaction, Filtration, Attraction, or Pulsion, &c. how admirable, and yet how plain and easy is it from them, the Fire-Engine, and other hydraulick Powers, to be accounted for? and in which is discovered the violent Elasticity and Force there is of Steam, Vapour, Water, or any other Fluid, when compressed or crowded into a little Room, which rises from the Roots of Plants in fine Tubes and Vessels, far beyond the precise Laws of Hydrostatics, (which do not admit of above 32 Foot,) even to 50, 60, or 70 Foot high, or more, from the great Force proceeding from the Rarefaction of the Juices in Plants, effected by the Sun, as the subterraneous and more latent Heat of enclosed Fires are said to facilitate the Rise of Springs in the Ground?

AND thus having, I think, undeniably proved, that Springs (especially those which are in *England*, and other Parts of *Europe*) do not derive their Causes from Air, Vapour, nor Rain, but rise thro' the Earth by the Laws of Rarefaction, Filtration, Attraction, &c. confirmed by almost an innumerable Number of Examples and Experiments, to be more plainly deducible from subterraneous, than other Causes above; I finish all with what the Scriptures, those divine Oracles of Reason, have delivered on this important Subject, which as a Christian, though an unworthy Member of that Body, I assent to and embrace, learning from *Gen. viii. v. 2. That the Fountains also of the Deep, and the Windows of Heaven were stopt, and the Rain from Heaven was stopt*; in which is seen a visible Distinction between Springs from the Deep, and Rains. *Job xxxviii. Verses 16. Hast thou entered into the Springs of the Sea, or hast thou walked in Search of the Depth? Amos ix. Verse 6. It is he that calleth* (or as it is in the Margin *that bundleth up the Waters of the Sea, and poureth them out upon the Face of the Earth.* And the Septuagint positively renders that Passage in *Genesis, Cap. ii. Verses 5, 6. That it was the River*
I
which

which went out of Eden, which watered the Face of the Earth before Rains had fallen; though our Translation says it was a Mist which then rose. And in Ezekiel, Chapter xxxi. Verse 4. they render it, that it was (as Doctor Plott observes) the Abyss which sent out Water for the watering of Plants. And in like Manner, Genesis vii. Verse 11. it is said, That in that Day were all the Fountains of the Deep broken up, and the Windows, (or as it is in the Margin,) the Flood-Gates of Heaven were opened; where is a manifest Distinction between the two Fountains of Rain above, and Sea-Water below. And in Proverbs viii. Verse 28. he saith, God has established the Clouds above; when he strengthened the Foundation of the Deep. The same also may be found Genesis xxxix. Verse 25. In the Blessings which Jacob conferred on his Son Joseph, even by the Almighty, who shall bless thee with Blessings from above, and of the Deep that lieth under. And of this Opinion also was Plato and Seneca, the first in his Phæd. Pag. 112. and the last in his Nat. Hist. Lib. iii. Cap. 4, 5. who say, that that great Conflux of Waters which is derived from the Sea, is raised through the Syrtes, Quick-sands, or Veins of the Earth from some immense deep Place. And this Gulph, says Plato, into which when all Rivers flow, they re-flow again. And in Job. xxviii. Verse 14. The Depth saith it is not in me, and the Sea saith it is not with me; all which import, that there is a Communication between those two Places distant from Rain.

I M U S T own my self somewhat concerned at the Pains which many great Men have taken to eradicate this serious and scriptural Truth; not that I think the Hills and Excrescencies of the Earth are of no use in natural Causes, or a Blemish of the Creation, as many Atheists and Unthinking would believe: The Wisdom of Providence is such, that Hills are placed in that high and exalted Manner we see them, that whether Springs owe their Original to Rain, Vapours, or the Sea, they are nevertheless subservient to the great End which God Almighty first designed them: Because from these it is, that Water is conveyed with more Ease into the humble Plains below, than it would otherwise be. And that whatever Vapours, &c. may do, which fall on some Hills beyond Sea, and run down with such Violence, as the learned Halley says, those of the Mountains of the Moon, and others of an unknown Name in Africa, (from whence the Nile and other Rivers proceeds,) do, yet in the Regions we inhabit; it is plain there is no such Thing, at least so visible, as that it should make us swerve from those serious and solid Truths of the Bible; nor that we may not conclude, as it is in Eccl. xi. 11.

76 *An Introduction to a General System*

That all Things which are of the Earth, shall turn to Earth again; and that which is of the Waters, shall return again into the Sea; and which is confirmed by one of the greatest Philosophers, as well as Princes, that the World ever produced; who tells us, Eccles. Chapter i. Verse 7. That all Rivers run into the Sea, yet the Sea is not full; unto the Place from whence Rivers come, thither they return: Thus those Springs run into the Rivers, from thence into the Sea, and then run back and press themselves through the Earth again, until free Leave be given them to come abroad, or, like Hannibal in the Alps, to work themselves a Way through.

C H A P. V.

Of the Method of discovering and searching for Springs; their Specifick Qualifications, and the like.

AUTHORS who have heretofore wrote of the Discovery and Production of Springs, have attributed it to divers Causes; sometimes to Earthquakes, as was the River *Ladon*, between *Helis* and *Magelenpolis*: Some suppose it to be to subterraneous Fires, which cause them to burst out. But the most remarkable Method in the Discovery of Springs, is as *Varennius* testifies, *Lib. I. Prop. 21. pag 261.* from a Swine which lay down and wallowed in the *Lunenburgh* Spring, the Hair of which, when the Sun arose, was by its drying Quality, so soon incrustated and grown dry, that the Spectators saw a whitish Colour upon him, which when they observed more curiously, they saw to be white Salt; which caused them to have Recourse to the Fountain, and forthwith they discovered and found out Springs, from which that City has since obtained all its Riches and Splendor: And ever since that, a Quadriparte-dry'd Hog has been kept in *Lunenburgh*, where the Parts hang upon a Beam, so wasted by Time, that there remains nothing to be seen but the Hide.

BUT to come nearer my Design: The same *Varennius*, in his *Geograph. General. Lib. I. Prop. 23. Cap. 262.* of the Elziver Edition, tells us from *Vitruvius, Lib. VIII. Cap. 1.* from whence also *Pliny* and *Palladius* have taken their Account, which *Bessonius* has also added in the third Edition, printed Anno 1569. That if Fountains do not flow of their own Accord, their Heads are to be sought for under Ground, and so collected together. Which Springs may be discovered in the following Manner: If you lay down on the

Fig:1

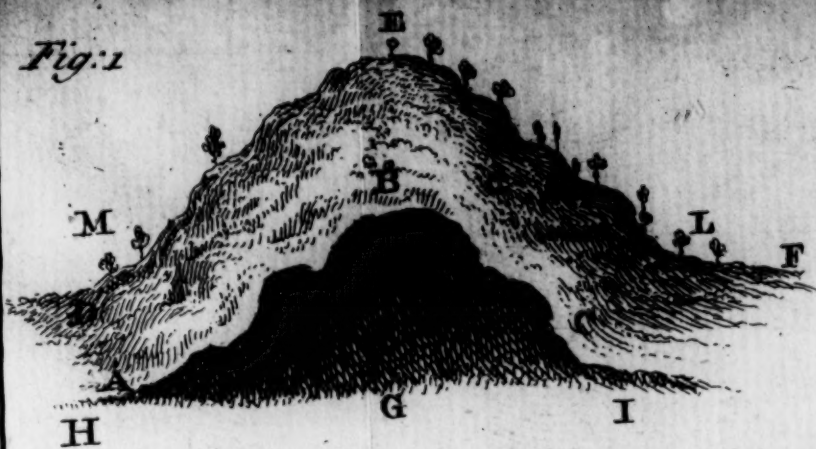


Fig:4



Fig 2

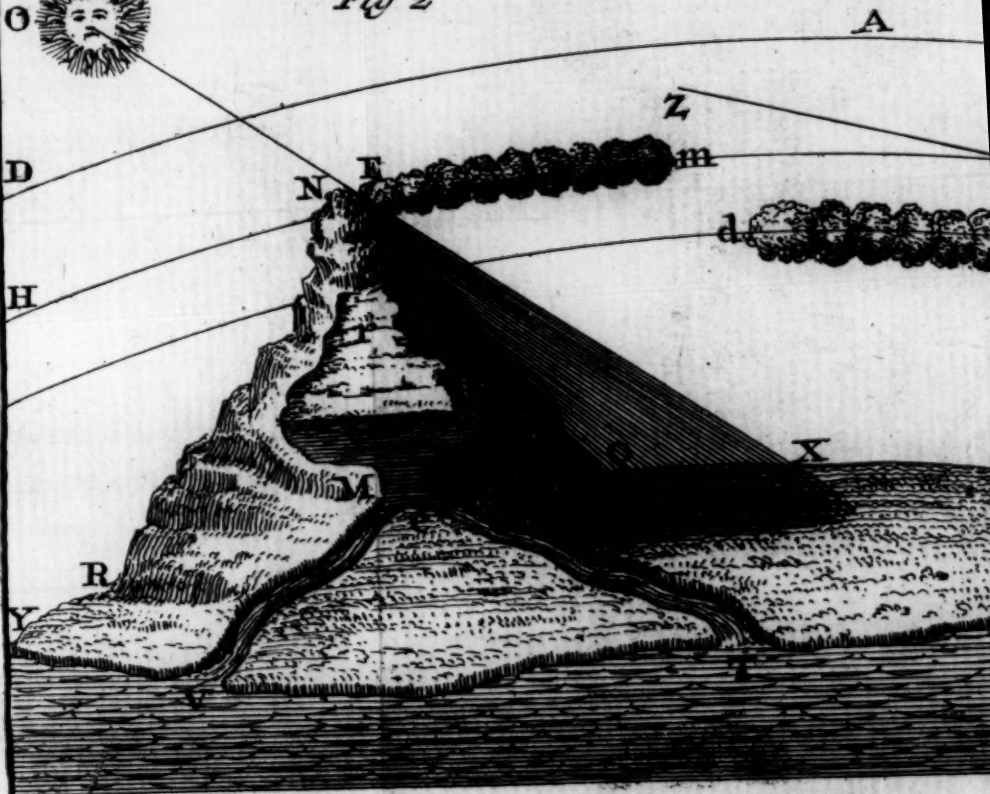


Fig:6



Fig:3

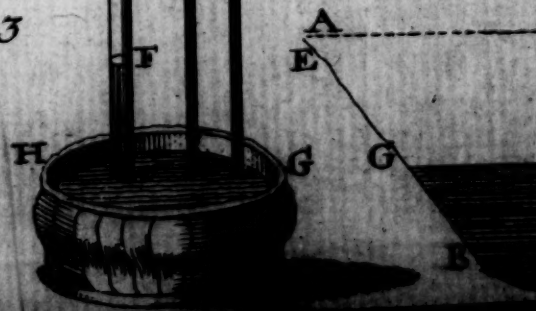


Fig: 4



Fig: 7



Fig: 8

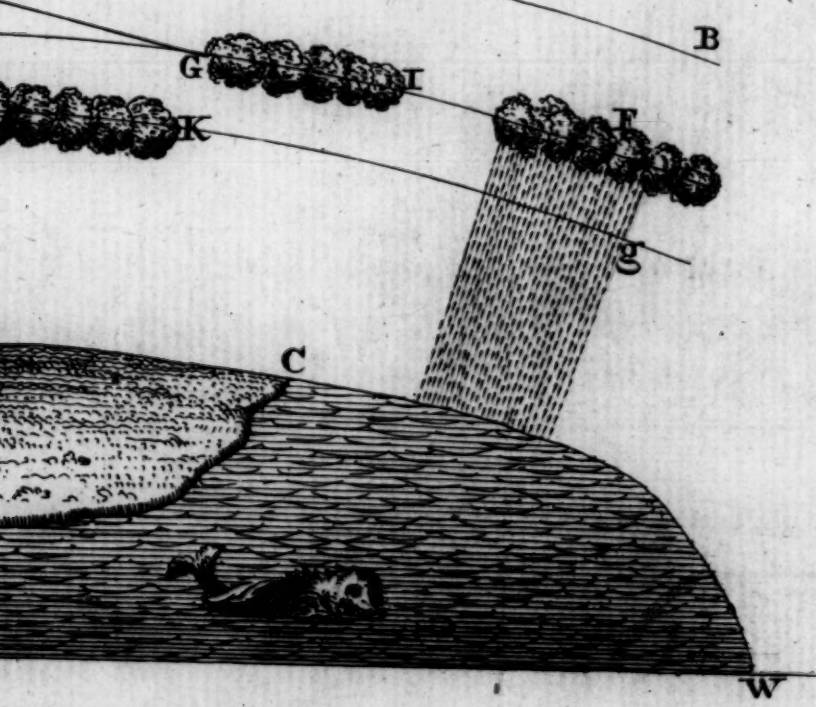
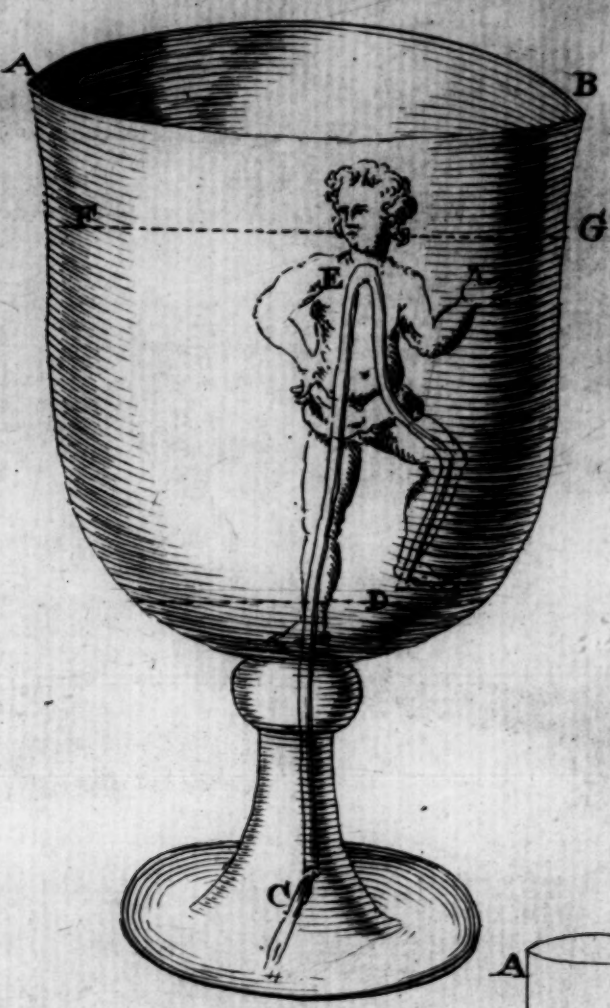


Fig: 5

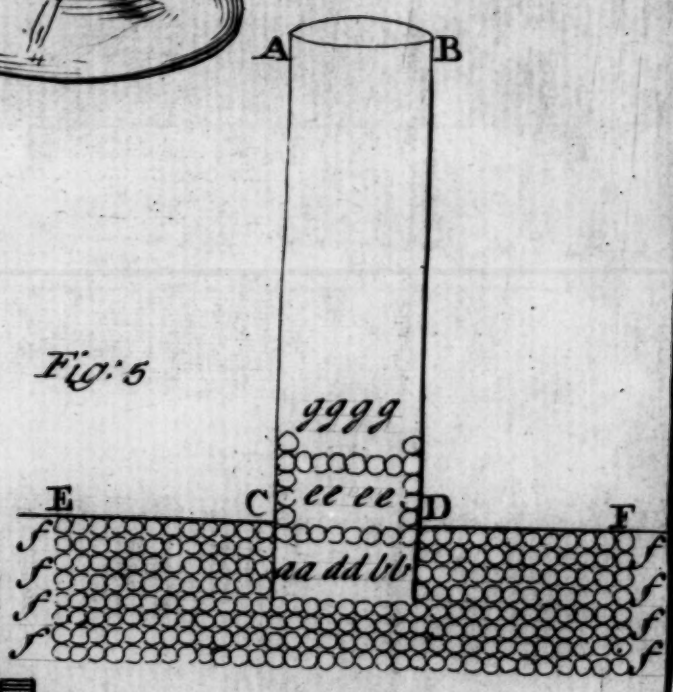


Fig: 9

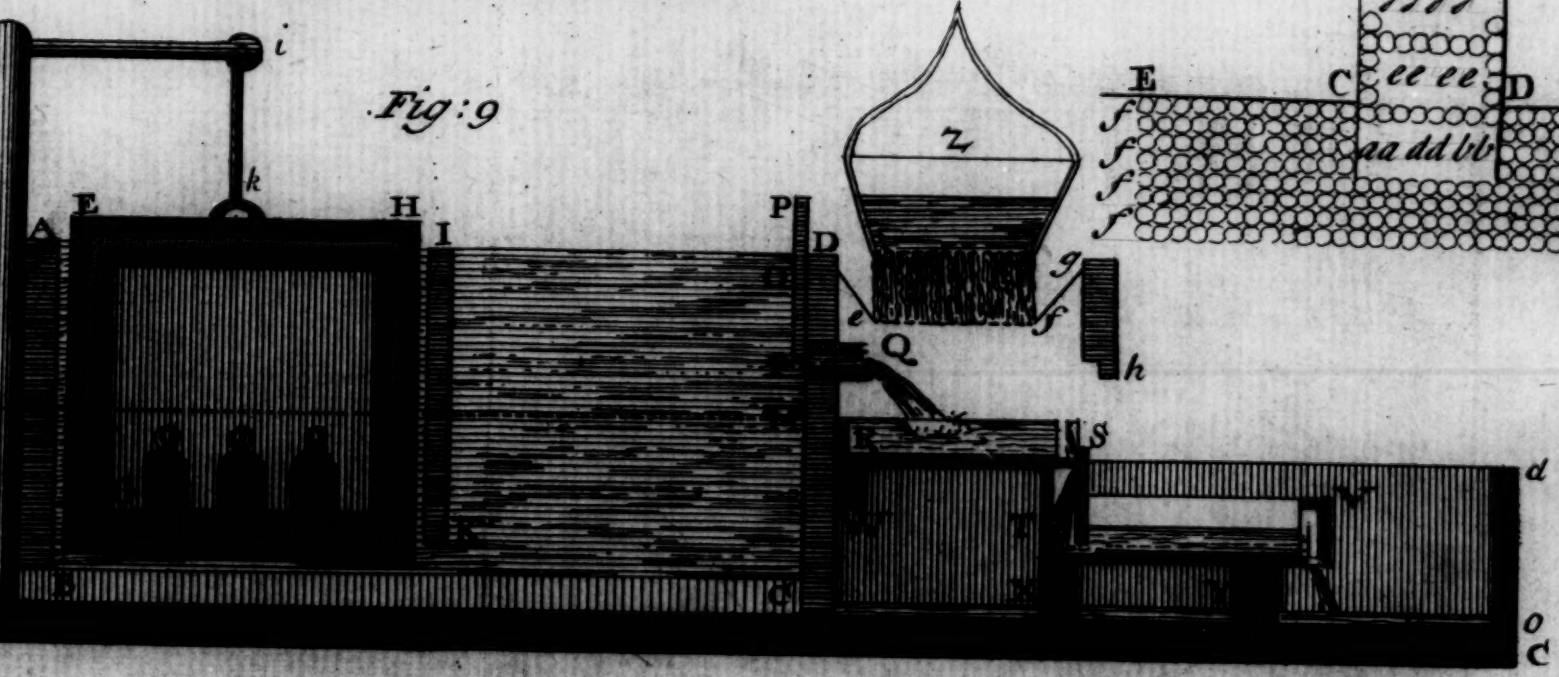
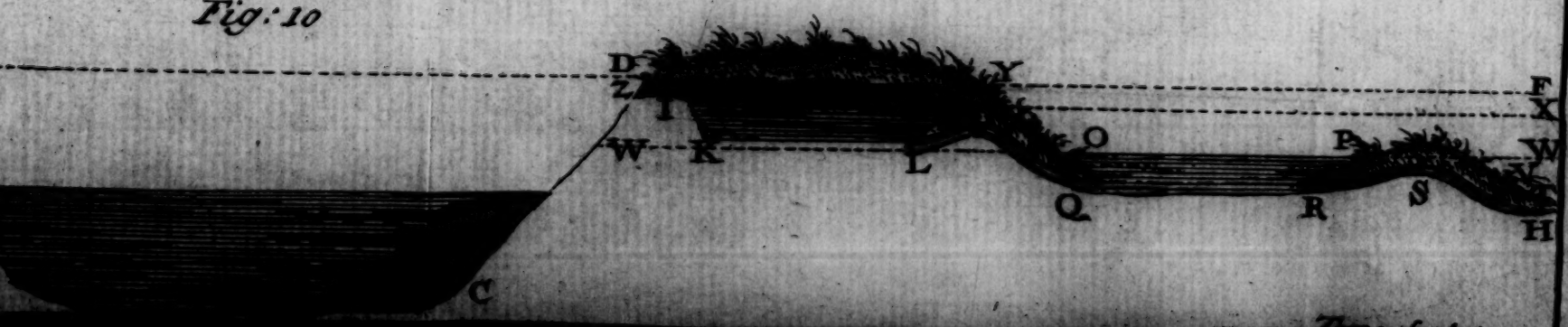


Fig: 10



Ground before the Sun rises on Places where you would seek for them, and having plac'd your Chin as close as you can, till it is, as it were, propp'd by the Earth, so that the Country thereabouts may be plainly seen; for by this Position the Sight won't wander any higher than it ought: If you keep your Chin unmov'd, it will give a certain Definition and true Level of the Parts where you are plac'd, and in those Places where you see Vapours gathering themselves together, and rising up into the Air, there you may dig; for this Sign never happens in a dry Place. Those therefore who seek for Water, should first consider what the Places are in which Water is to be found. In the following Places Springs are certain and good: In Chalk (says some) it is fine, but rises not very high, but (whatever the Antients thought of it) it is the best Water of all. In Sandy Gravel also it is fine; but if it is found in low Places, (these are generally Rain-Springs,) and then it will be muddy, and unfavoury; but in black Soils there are fine thin Distillations found, which are collected, as they subside, from Winters Rains in clayey Grounds, and those have the best of Tastes: In Ground which is a clear Gravel, Springs abound but little, and the Veins are not certain; but those are extraordinary sweet. In large pebbly Gravel, and in Sand, Stone, or loose Veins of Coal, they are more stable and certain; and these have all a good Taste. They are Plenty also in red Stone, and good if they don't slip away, and run off through the Interventions thereof. They flow plentifully also under the Foot of Mountains, and in stony Places; these are very cold, but very healthy: But the Water which is found in champagnious open Places (such is the Water in all stagnated Ponds) is thick, betwixt hot and cold, and not sweet, unless it be that which springs out of the Bottoms of Mountains, and takes its Course into the Middle of large Plains: And where they are shaded with the Covering of Trees, there they excel the Sweetness of Mountain Springs.

MANY other are the Signs where good Springs (according to the Antients, especially * *Coronarius*) are found; who have intimated, that wherever the Twig Withy, Fleabane, Reeds, Trefoil, Pond-Grass, and the Bull-Rush grow, in great Plenty, 'tis there you may most probably find Water; but Water, says the same Author, is to be found more constantly by the following Experiment.

WHEREVER you are desirous of finding it with Certainty, there must a Ditch be made of three Foot deep, and taking a leaden Vessel, or earthen Pot, made in the Form of a Semicircle, at Sunset rub it

it over with Oil; then prepare a Piece of Wool, half a Foot long, and washing it very carefully, and drying it afterwards, you are to bind on a small Stone in the Middle of it, and fix it in the Middle of the Pot or Vessel with Wax: Then turn the Mouth of the Pot downwards in the Trench you have thus caus'd to be dug, taking a particular Care, that after it is so turn'd the Wool may hang down in the Middle of the Vessel; which done, you must cover your Vessel with Earth a Foot thick, and keeping it so all Night. Uncover it in the Morning, before the Sun rises; and if there be Water in the Place, you will perceive the Pot to have small dewy Drops hanging on its Bottom, and the Wool to be wet.

IF the Wool be very full of Water, and the Drops hanging on the Pot be very large, you may conclude you are not very far from the Spring; but if it be only moist, though there be a Spring in that Place, yet it lies very low, and not to be come at without a great Expence, and much Difficulty; but if none of these Symptoms appear, you must make the Experiment in another Place.

THERE are other Methods by which Water may be discover'd; as by observing the Nature of the Soil. If it be a black fat Soil, and abound with Pebbles of a black or yellowish Colour, there you need not fear the Want of Water; the same may be said, if the Soil be glutinous or clayey; and also by the natural Produce of it, (as before,) you may discover where Springs are, as where Water-Plantain, the Sun-Flower, Reed-Grass, or Ox-bane, Brambles, or Shavegrasses, Calamint, Mat-Rushes, Maidenhair, Melilot, Sower Sorrel, or Ditch-Dock, Cinquefoil, Bloodwort, Nightshade, Water Millfoil, Colts-foot, grow; and where they grow in greatest Abundance, there you will find the largest Springs.

To this may be added what Mr. *Bradley*, in *Numb. I.* of one of his late *Miscellany Papers* observes, from his ingenious Friend *Charles du Bois Esq;* of the *Stellaria Aquatica* & *Saxifraga aurea*; which whether certain Tokens of Springs, a little Practice may determine.

Now as to Soils; those which are black and deep, produce (as already noted from *Vitruvius*, *Pliny*, and others) the most durable and strongest Waters; those which are most clayey, are the wateriest, and the Waters are the sweetest; though in *England* we generally suppose, that our Chalks produce the finest Water, as do many of our fine Sands that which is admirable, as I have often observ'd at *Spy-Pack*, near *Sandy-Lane*, the Seat of the *Bayntons*, on the Road to the *Bath*, where there is some of the finest sweetest Water in the World, and on a fine light Sand, as may be observ'd by those that pass that Way. To proceed with the Antients;

THOSE

THOSE Waters that lie deepest are the sweetest and most durable; for those which are found near the Surface; most commonly proceed from Rain, and cease with their Cause: Wherefore it is necessary to dig deep, till you come to the very Fountain-Head, and there you need not doubt of its being lasting and flowing continually, though there are, indeed, some Springs that lie within eight or ten Foot of the Surface, that are as durable as any of those that lie twenty or thirty Fathom, and that in Countries where no River appears; but this is not so frequently to be met with, unless it is where Rivers do abound, which do, in a particular Manner, influence those Wells that lie near them.

SOME there are that try the following Experiment to find Water: They dig a Ditch a Foot broad, and three Foot deep, and about Noon hang a dry Sponge in the Middle thereof for three Hours, covering it close with great Reeds, and if the Sponge, when taken thence is wet, they proceed to dig, assuring themselves of Water; but if it be dry, it is in vain to dig or search for it. *Corral*, says our aforementioned Author, pounded and cast into Water corrects the Bitterness of it, and a Bag of Barley thrown into it has the same Effect.

Vitruvius, *Lib. x. Cap. 6.* says, that the Antients made several Conservatories, out of which the Water passed (as may be supposed) very leisurely one into another, reserving the last for that out of which the Water was to be taken for use, and the others were for the Sediment which is in Water, particularly those that are a little muddy: They likewise put Salt into their Water to make it more subtle.

Democritus, another Author of great Antiquity and Experience, as the aforementioned *Coronarius*, in his Writing concerning Agriculture, *Lib. ii. Cap. 5. Pag. 29*, has it, assures us, that those who have taken their Observations from the Hydrophanticks, or Discoverers of Water, aver, that Flats or extensive Plains, are commonly most destitute of Water, as rising Grounds seldom fail of abounding therewith; and those Eminencies that are the most shaded with Trees, have generally the greatest Share thereof; and it is observeable, that those Waters which are found in Plains, are most commonly, brackish; whereas those that are discovered in an Eminence are generally sweet, except they are changed by some accidental Cause, as Salt, Nitre, Allum, Sulphur, or the like.

THE natural Cause of the foregoing Effects may be thus assigned, viz. that the Sun always attracts the smallest and lightest Particles, out of the Water, and leaves the grossest subsiding; wherefore the
Sun

80 *An Introduction to a General System*

Sun lying all Day long upon the Plains, (and the Water being by its natural Level the less moving,) exhales the Moisture, and dissolves it into Vapour. From whence it follows, that some Plains are almost destitute of Water in the hot Summer Months; and the small Quantity which remains, is salt and unpleasant to the Taste, the sweet and light Particles being drawn off from those that are more gross and unpleasant; and to this may be assigned (says my ingenious Author) the saline Quality of the Sea: But the Sun shining only obliquely on the Sides, and Verticities of Hills, and the Cadence Motion or Fall of Water (call it which you will) being more precipitate from Hills and rising Grounds, than from all low Levels and humble Plains, the Sun has not the same Influence on the first, as on the last, and, consequently, the Water is not only the more plentiful, but also more pleasant; and it is observable that those Hills that are situate towards the North, abound with more Plenty of Water than those that are situate towards the South; and those that are shaded with Woods, than those which are naked.

To conclude this Account; *Cassiodorus*, and others, (as the ingenious Author of the *Theory and Practice of Gardening* has it,) set down, that wherever you can discover Swarms of small Flies hovering and pitching about one and the same Place, that they are certain Signs that Water is there.

From this View into the Records of Antiquity, we see what the Antients have said concerning the Method of Discovering of Water, most of which is agreeable to the Observations of modern Practitioners. The several Kinds of Weeds, in this Chapter before recited, are certain Indications that Water, (if it does not break out,) is near at Hand: And to this may be added, that those Kinds of Herbs grow on moory black Land on the Sides of Hills, and where the Ground is mix'd with Pebbly Gravel or Rock, that is of a dusky, brown, sandy Colour. But there is not a more certain Sign of Water in the World than where Alder-Wood grows naturally, and of its own Accord: Nor does the Oak disdain to be an Inhabitant of those moist Hills, there being (besides Observations of that Kind made in other Places) an Oak in *Spy-Park*, before named, through the Roots of which there issues out at least 200 Hogsheads of Water in a Day; and there are in that beautiful, (though now forlorn Place,) at least thirty or forty of such Springs, besides innumerable others that lie without it.

Corollary

of Hydrostaticks and Hydraulicks. 81

AFTER this so particular and succinct an Account of the ancient and modern Observations for the Discovery of Springs, their Situation &c. it will be requisite that we proceed to the Operation it self, such as is founded not only on Speculation, but on the undoubted Force of Fact and Practice.

THOSE who have been conversant in Mines and Cole-Works observe, that there are (as I think is before slightly intimated) two Sorts of Springs; those that lie near the Surface, and are suppos'd to proceed entirely from Rain; and those that lie deeper, which proceed from a much more remote Cause. It would then be dangerous, in the first of these Cases, to dig deeper than the Surface where they first appear, least they should take a wrong Current, and instead of breaking out Sideways, sink beneath their Cause, and be lost in the Crannies and Openings of such Rocks of Stone and Gravel as lie contiguous thereto; but those are either stronger or weaker, as they happen to lodge or fall on Earths that are in their Nature more or less glutinous and clayey, and consequently tenacious of Water; or are otherwise of a more arenacious, gravelly, sandy, or of a drying Chalk and whitish Earth, or, which is very common, of a flinty or hollow Substance; for contrary to the Opinion of some, otherwise very ingenious and good Reasoners in a Closet, or in Books, 'tis to one or more of these Causes, and these only, that Springs abound more or less in any Country whatsoever. And these uppermost Springs you must seek after with Caution; but those that lie lower you need not fear of injuring, as the many deep Wells lately made in several barren Places of *England* are a sure Testimony.

WHEN you have pitch'd upon a Place that is proper to bore for Water, by some one or more of the Signs I have laid down, be provided with a large Augar, that may be grafted at every five or six Foot; and having made a round or square Hole on the Top of the Ground where you intend to bore, about three or four Foot wide, or more, to give Room for your Workmen to make their Experiment the better, you are to proceed; and when you have bored one Length of your Augar of four or five Foot, as aforesaid, then graft on another Length, and so on, till you come down to the Water, every now and then pulling out your Augar, and cleansing of it, to see what Soil you bore through.

BUT of these Kind of Augars, and the Way and Method of boring, you will be better inform'd at the Cole-Works of *Durham*, as *Newcastle*, *Sunderland*, &c. in the *North*, and at the Cole-Works in *York* and *Lancashire*; as also at those of *Mendipp* in *Somersetshire*, where both Lead and Coal are dug; as also in *Derbyshire*, and elsewhere.

I SHALL finish this Chapter when I have given, besides an Observation or two about Wells, an Account which has been related to me with much Seriousness; and that was in *Spain*, when the Confederate Armies were there in the last Wars. When they wanted Water on their March, or otherwise, they dug down such a Pit as I have been before describing, and with the Muzzles of their Muskets have fired four or five Times down into the Ground, which has caused the Water to boil up immediately for their present Use. But I much doubt of such Success with us here in *England*, especially in all upland and champian Ground, where alone Water is wanted.

BEFORE I conclude this Chapter it may not be improper to make a short Enquiry into the Nature and Goodness of Water.

VARENNIUS, in his general Account of the Properties of Water, (*Cap. xvii. Prop. 1.*) lays it down as an undoubted Maxim, that there is no Water pure and elementary, but contains, or has mix'd with it, small Particles of Matter, (such as are found in all terrestrial Bodies,) which (says he) is prov'd from the Difference there is in their Taste, as well as from Distillation itself. And so all Physicians agree, that Water which is simple and unmix'd, has no Existence in Nature; the Cause of which is the various and perpetual Agitation of the Particles of Matter of which all Bodies are composed. Mineral Waters in particular (says he) receive their spirituous Particles from the Mixture of those which are heterogenous or different from them; but Rains, and Air itself, touching or pressing upon Water, are compos'd of Particles very many and different from each other; from whence he infers, by way of Corollary, that all Waters are compos'd of Particles of a different Nature which are mix'd with them. And that I may explain him the better, I add, those that are best for Plants with such Particles as are nitrous and earthy, and which may be appropriated to all the general Purposes of Life, and those which are more spirituous and Physical (being impregnated with Sulphur and the like) to all extraordinary Cases, such as acute Pains, Aches, and the like.

BUT I need not enlarge on the Intermixture or different Properties of Water, since that (especially as it respects Vegetation) is so excellently well done by the learned Dr. *Woodward*, in an Essay of his, publish'd in the *Transactions of the Royal Society*, as well as to the curious *Examen* of the learned *Boyle*, and others, to which I refer my Reader. To proceed then to the different Denominations of this great Part of Nature.

SPIRITUOUS Waters are chiefly call'd volatile, and are found in Minerals, but yet contain some fix'd Particles; but besides them there are no notable Properties that may be extracted or drawn from them. From whence he concludes, that all watry Bodies take their Denomination from these two Properties, (*viz.*) fix'd or solid, volatile or spirituous; and these contain all of them Particles of a mineral Nature.

BUT to omit Minerals, and to proceed to those Properties which are the most essential to the common Purposes of Life; the same ingenious Author, *Cap. XVI. Prop. 24.* of the aforementioned Treatise, as he has it from *Vitruvius*, that those Waters which flow swiftly, and in an open Stream, are the best; that it should be minded whether the Men which liv'd near those Fountains, were strong and lusty; and if they were of a Soldier's Mien, of a clear Complexion, not Bandy-Legg'd, nor Blear-Ey'd, those Waters were the most to be approv'd of.

ALSO if the Fountains were new dug, and the Water sprinkled on a *Corinthian*, or any other Vessel made of good Brass, if it left no Spots upon it, then that Water was the best in its Kind.

IN like Manner, if such Water was heated in any Cauldron or Brass Pot, and afterwards left to settle, and be pour'd off, and that neither Sand, nor any other slimy Matter was found at the bottom of the said Pot, or Cauldron, that then such Water must be accounted good.

So also if any Legumes be put into a Vessel, and set over a Fire, in such Water, if those Legumes are quickly boil'd, it is an Indication that the Water is good and healthy.

WHEN you dig for a Well, great Care ought to be taken, not only in strewing the Sides to keep the Earth from tumbling in upon the Workmen, but also to take Care that the Effluvia's of the Water (which if bad) do not hurt them; for it has been often remark'd, that the Water which is under the Earth, hath many bad Qualities, and emits Vapours, which often stifle those which work in the Well after they are dug, and the Water begins to gather together. To prevent which, the Ancients, as *Vitruvius* has it, *Lib. x. Chap. 6.* had this Precaution, To let a Lamp gently down into it, and if it extinguish'd it, they took it for an infallible Sign that the Water was bad; and I add, that this Care, and the curious Observation whether Water is good, or no, is of great Use to those that would live and enjoy those uninterrupted Scenes of Health, which alone make Life pleasant; for a very worthy and honourable Nobleman of my Acquaintance in the County of *Southampton*, was obliged to desist from Building, though on a lofty and noble Situation, on that Account.

C H A P. VI.

Of the Instruments proper for, and Method of taking the Levels or Falls of Water, from a Spring-Head to a Mansion-House, Building, Reservoir, Garden, Pond, &c. And the Allowances to be made in Levelling, for the Curvature of the Earth, Descent of the Water, and the like.

THE Original of Springs, with the Manner of finding them out, being thus set down, what follows next in Course is the taking the exact Levels, making proper Allowance for the Curvature of the Earth, and adjusting the Fall or Current which is generally allow'd for the Descent of Water. But first, of the Instruments for that Purpose :

THE Ancients, as *Vitruvius, Lib. viii. Chap. 6*, writes, “ made use of an Instrument they called *Corrobates*, which was directed by a Lead, and by Water when the Wind hinder'd them from making use of the Lead; and allowed in the Channels or Sewers, of the Aqueducts for every hundred Foot half a Foot of Declination or Sloping; and if any Hills were in their Way, they dug thro' them, making Vents to give Air at convenient Distances.”

THE ancientest Instrument us'd with us, as well as one of the most certain, is the *Water-Level*, describ'd by *Blythe*, in his *Improvements of Husbandry*, (at the Beginning,) which must be own'd to be one of the best of all, in the operative Part, at least of Works of the Kind we are now upon, provided the Weather be still; but if it be Ruffling, it is like all other Instruments, difficult to use. However, with some Improvements I have made to it, which will be more particularly declared in some subsequent Pages of this Chapter, when I come to treat of the directing the Level in the making Trenches for conveying of Water, it will be easy to use.

BUT for the first taking of Levels, especially those which run any Distance, these that follow are in the most Esteem amongst the Ingenious:

IN the first Place, I shall not (in Regard to my Profession as a Gardener) pass by our common Garden *Level*, describ'd as it is in Miniature, *Fig. 1. Tab seq.* where A A represents the two upper Sides of the *Level*, B B the under Sides, resting on the Heads.

Heads of two Stakes, which I may call also by that Name of B B. And the Lead, which is fastened to a fine Pack-thread, hanging from C towards D, holding a Plumb at a which when the *Level* is truly Horizontal, plays down through the dotted or prick'd Line. This Instrument, by the Help of the Boning-Staff P Q R of about four Foot and a half long, will dispatch any Work or Labour of this Kind as well as any yet to come, though not so portable: But if you stick a Knife or Knives into the Stakes B B, any where towards the Top, and make them level to one another, by Application of the said Boning-Staves, you may take any distant View when the Weather is fine and clear; and by sticking the Knives *ad Libitum* into these Stakes, you may go on better than when you drive them down to any determinate Height, and the Work will dispatch quicker.

IN the Works of the celebrated Monsieur *Le Bion*, who is, or was Mathematical Instrument-Maker to the *French King*, I find a Telescope Plumb *Level*, (vid. *Fig. 2. Tab. seq.*) the Construction of which, take as follows:

THIS Instrument (says *Le Bion*) is compos'd of two Branches joined together at Right Angles; whereof that carrying the Thread and Plummet is about a Foot and a half, or two Foot long.

THIS Thread is hung towards the Top of the Branch, at the Point 2; the middle of the Branch, where the Thread passes, is hollow, so that it may not touch in any Place but towards the Bottom, at the Place 3, where there is a little Blade of Silver, on which is drawn a Line perpendicular to the Telescope.

THE said Cavity is covered by two Pieces of Brass, making, as it were, a kind of Case, lest the Wind should agitate the Thread; for which Reason there is also a Glass-Covering to the Silver Blade, to the End that we may see when the Plummet plays upon the Perpendicular. The Telescope is fastened to the other Branch, which is about two Foot long, and is made like other Telescopes. All the Exactness of this Instrument consists in its having the Telescope at Right Angles with the Perpendicular.

THIS Instrument has also a Ball and Socket, as other Instruments of this Kind have; and there are some of them made of Brass or Iron, whose Telescope, and the Cavity, in which is included the Thread carrying the Plummet, is about four or five Foot long, in order to level great Distances at once. The Telescope is about an Inch and a half Diameter, and the Case in which the Thread carrying the Plummet is enclosed, is about two Inches wide, and half an Inch thick. This Case is fasten'd (with Screws in the middle) to the Telescope, so that they may be at Right-Angles one to another; and at the two Ends of the Telescope are adjusted two broad Circles, in which the
Telescope

Telescope exactly turns; which Circles being flat underneath, are fasten'd to a strong Iron Rule.

THIS *Level* is supported by three Legs, as other Instruments are, fasten'd into the Globe at D, under the Ball and Socket mark'd 4, where there is a Screw to make the Ball go stiff; also there are two Openings, cover'd with Glasses, enclosed in little Brass Frames, which open so that the Thread and the Plummet may be hung to the Top of the Case, and play upon two little Silver Blades in a Line drawn on them perpendicular to the Telescope. These Blades are placed against the Openings of the Case, and the Telescope is like that before spoken of.

THE two little Instruments mark'd F and H are *French Levels*, and are founded upon the same Principles as the preceding ones; the Figures whereof are sufficient to shew their Construction and Use.

AMONGST all the *Levels* which have been or may be produc'd, there is none which, for Portableness, Cheapness, and, I may add, Certainty and Dispatch, that exceeds that which I am about to describe in this Place, it being what any ordinary Countryman may make or purchase for about eight or ten Shillings; whereas other *Levels* there are, and which will be necessarily describ'd in the Series of this Chapter, which will cost five or six Pounds.

LE BION has this amongst his Collection of curious Instruments for Levelling; which he says, is a Tube made of Brass, or other like solid Matter, about three Foot long, and twelve or fifteen Lines Diameter, whose Ends are turned up at Right Angles for receiving two Glass Tubes, three or four Inches long, fasten'd on them with Wax or Mastick; at the Middle, and underneath this Tube, is fixed a Ferril for placing it upon its Foot. This *Level*, though it be a very simple one, is very commodious for levelling small Distances. Thus far *Le Bion*.

BUT long before I saw this Design from *France*, I remember to have seen one of the same Kind in *England*, in the Hands of my very ingenious Friend Mr. *Jacob Wells*, of *Farringdon, Berks*, founded upon the same Reasons, though not made exactly in the same Manner as the former was; it consisted of a Piece of Heart of Oak, (if I remember right, for it was some Years ago I saw it,) that was about two Inches square, in the middle of which, there was a large Groove, into which was fix'd (as I take it) a Tin Tube, of about two and half or three Foot long, being the Length of the Piece of Wood turn'd up at the End, into which, at a a, was put in two Tubes of Glass, of an equal Length, reaching to b b; now into either End of the
Glass

Glass Tubes, which are always open, you may pour in Water so high, 'till it reaches the prick'd Line c c, or thereabouts.

THIS Instrument may be fix'd on a Tripod, or a plain Table, or any other Instrument for Surveying, is flipp'd into it at B; and if you manage it with any kind of Dexterity or Discretion, it will immediately form a Level, as at c c, before mentioned, which though it be farther off, or nearer to a a, is not material; the Water which is in the Tube naturally resting on a Level, over which you are to take your View.

BUT if you have a Mind to enlarge your View a great Way, you may frame in a little Post on one Side of your *Level* at O, which shall have a Screw fix'd into it at P, and may be either rais'd higher or lower at Pleasure, as your Water is in the Tubes, through which you may have Sight to look at N^o 2, 2. as you do through other *Levels*. The *Rationale* of this, and all *Levels* of this Kind, are, that Water naturally places it self level; and therefore the Heighth of the Water in the Glass Tubes will be always the same, in respect to the Center of the Earth.

THE next *Level*, I shall mention, is a common *Spirit-Level*, which which is describ'd in Miniature, *Fig. 4. Tab. seq.* having a Bubble of Quicksilver, or, which is better, Spirit of Wine, or any other Liquor discoloured, to make it the more visible. This Spirit being enclos'd in a small Glass Tube of two or three Lines Diameter, in a Piece of Wood or Brass, about two or three Inches square, has Degrees on it on the Upper at a, running each Way towards the Ends b b, in equal Parts as far as 10; now the Length of the Bubble may be such, as to reach from three to three Degrees each Way, or from four to four, and so on. But wheresoever it reaches, it is proper it should be an equal Number of Degrees, distant from the Center a, be it what they will. This stands upon three Legs, and has generally a Ball and Socket, as other Instruments of this Kind have, and is used after the same Manner. There are, that have Telescopes to them, one of which I shall produce by and by; and shall now proceed to those made of Air, which are not as yet (at least as I have seen) common in *England*.

IN the Works of the ingenious *Le Bion*, before mentioned, there are the Draughts of two Kinds of the *Air-Level*, one whereof without, and the other with a Telescope annex'd to it; the Description of both which, take as follows. *Vid. Fig. 5. Tab. seq.*

It is composed of a Tube set in Brass, of about eight Inches long, and seven or eight Lines Diameter, which is left open in the Middle, for seeing the Bubble of Air at top.

It is carried upon a very strong strait Rule, about a Foot long; at the Ends of which are placed two Sights, exactly of the same Height, and like that of N^o 3, which has a square Hole therein, having two Fillets of Brass very finely filed, crossing one another at Right Angles, in the middle of which Fillets is drilled a little Hole.

THERE is fasten'd a little thin Piece of Brass to this Sight, with a small headed Rivet, to stop the said Square's opening when there is Occasion, and having a little Hole drill'd through it, answering to that which is in the Middle of the Fillets. The Brass Tube is fasten'd upon the Rule by Means of two Screws, one of which, mark'd 4, serves to raise or depress the Tube at Pleasure, for placing it level, and making it agree with the Sights.

THE Top of the Ball and Socket is rivetted to a little Rule that springs, one of whose Ends is fasten'd with two Screws to a great Rule, and at the other End there is a Screw mark'd 5, serving for the Raising or Depression of the whole Instrument, which is nearly level.

THE Manner of adjusting this *Level* is easy; for you need but place it upon its Foot, so that the Bubble of Air may be exactly in the Middle of the Tube, then shutting the Sight next the Eye, and opening the other, the Point of the Object which is cut by the Horizontal Fillet is level with the Eye. And to know whether the *Air-Level* agrees well with the Sights, you must turn the Instrument quite about, and shut the Sight which before was open'd, and open the other; then looking through the little Hole, if the same Point of the Object before observ'd be cut by the Horizontal Fillet, it is a Sign that the *Level* is just; but if there be found any Difference, the Tube must be rais'd or depress'd by Means of the Screw N^o 4, till the Sights agree with the *Level*, that is, that looking at an Object, the Bubble of Air being in the Middle, and afterwards turning the Instrument about, the same Object may be seen.

THE *Air-Level* B is a very strait Glass Tube, everywhere of the same Thickness, of an undetermined Length, and of a Thickness proportionable, being filled to a Drop with Spirit of Wine, or other Liquor, not subject to freeze. The Ends of the Tubes are hermetically sealed that is, the End through which the Spirit of Wine is pour'd must afterwards be clos'd, by heating it with the Flame of a Lamp, blown through a little Brass Tube to make the Heat the greater; and then, when the Glass is become soft, the End must be clos'd up.

WHEN this Instrument is perfectly level, the Bubble of Air will fix it self just in the Middle; and when it is not level, the Bubble of Air will rise to the Top.

THE

THE *Level D* is a little Glass Tube, inclosed within another made of Brass, fasten'd upon a Rule perfectly equal in Thickness, and serves to know whether the Plane be a *Level*, or no.

THE next *Level*, I shall produce, is a Telescope *Air-Level*, *Vid. Fig. 6. Tab. seq.* which is also an Invention of the famous *French Instrument-Maker Le Bion*, and is of great Use in discovering Objects at a great Distance. The Telescope is in a little Brass Tube, about fifteen Inches long, fasten'd upon the same Rule as the *Level*, which ought to be of a good Thickness, and very straight.

AT the End of the Tube of the Telescope mark'd 1, enters the little Tube 1, carrying the Eye-Glass, and a human Hair, horizontally plac'd, in the Focus of the Object-Glass 2; this little Tube may be drawn out, or push'd into the great one, for adjusting the Telescope to different Sights; and at the other End of the Telescope is placed the Object-Glass, whose Construction is the same as that beforementioned, belonging to the Semicircle.

THE whole Body of the Telescope is fasten'd to the Rule, as well as the *Level*, with Screws, upon two little square Plates, solder'd towards the Ends of each Tube, which ought to be perfectly equal in Thickness. The Screw 3 is for raising or lowering the little Fork carrying the human Hair, and making it agree with the Bubble of Air, when the Instrument is level; and the Screw 4 is for making the Bubble of Air agree with the Telescope. Underneath the Rule is also a Brass Plate, with Springs to it, having a Ball and Socket fasten'd thereto.

THE *Level E* places itself, and is compos'd of a pretty thick Brass Rule, about one Foot long, and an Inch broad, having two Sights, of the same Height, placed at the Ends of the Rule; and in the midst there is a kind of a Beam, (almost like those of common Scales,) for suspending the *Level* freely.

AT the Bottom of the said Rule is screw'd on a Piece of Brass, likewise carrying a pretty heavy Ball of Brass. All the Exactness of this Instrument consists in a perfect Equilibrium; to know which, is easy: For holding the Instrument suspended by its Ring, and having espied some Object through the Sights, you need but turn the Instrument about, and observe whether the aforesaid Object appears of the same Height through the Sights; and if it does, the Instrument is perfectly in Equilibrio; but if the Object appears a little higher or lower, you may remedy it, by removing the Piece of Brass, carrying the Ball exactly in the Middle of the Point of Suspension, and then it must be fix'd with a Screw, because, by Experience, it was found the Instrument was level.

THE next *Level* I shall produce from this *French* Author, is said by him, to be the Contrivance of that truly ingenious and great Man, Monsieur *Hugens*, whose Name and Memory has been so long celebrated in the learned World. *Vid. Fig. 7. Tab. seq.*

IT is a Telescope of about fifteen or eighteen Inches long, being in the Form of a Cylinder, and going through a Ferril, in which it is fasten'd by the Middle. This Ferril has two flat Branches *b, b*, one above, and the other below, about a fourth Part of the Telescope in Length. At the Ends of these two Branches, are fasten'd little moving Pieces, which carry two Rings, by one of which the Telescope is suspended to a Hook, at the End of the Screw 3; and by the other a pretty heavy Weight is suspended, in order to keep the Telescope in *Equilibrio*. This Weight hangs in the Box 5, which is almost fill'd with Lin-seed Oil, Oil of Walnuts, or any Thing else which will not coagulate, for the more aptly setting the Balances of the Weight and Telescope.

THIS Instrument carries sometimes two Telescopes, close and very parallel to each other, the Eye-Glass of one being on one Side, and the Eye-Glass of the other being on the opposite Side, that so one may see on both Sides, without turning the *Level*. If the Tube of the Telescope, being suspended, be not found level, as it will often happen, put a Ferril or Ring, mark'd 4, upon it, which may be slid along the Tube, for placing it level, and keeping it so; and this must be if there be two Telescopes. It must be noted, that there is a human Hair, horizontally strained, and fasten'd to a little Fork, in the Focus of the Object-Glass of each Telescope, which may be rais'd or depress'd, by Means of a little Screw, as has been already mentioned.

FOR proving this *Level*, having suspended it by one of the Branches, observe some distant Object through the Telescope, with the Weight not hung on, and very exactly mark the Point of the Object cut by the Hair of the Telescope; then hanging the Weight on, if the horizontal Hair answers the same Point of the said Object, it is a Sign that the Center of the Gravity of the Telescope and Weight, is precisely in a right Line, joining the two Points of Suspension, which continued, would pass through the Center of the Earth.

BUT if it otherwise happens, you must remedy it by sliding the little Ring backwards or forwards. Having thus adjusted the Telescope, that the same Point of an Object be seen, as well before the Weight is hung on, as afterwards, you must turn it upside down, by suspending it to the Branch which was lowermost, and hanging the Weight upon the other; then if the Hair in the Telescope cuts the
the

the aforesaid Point of the Object, it is manifest, that that Point of the Object is in the Horizontal Plane with the Center of the Tube of the Telescope; but if the Hair does not cut that Point of the Object, it must be rais'd or lower'd, by Means of the Screw, till it does. *Note*, You must every now and then prove this Instrument, for Fear least some Alteration has happened thereto.

THE Hook on which this Instrument is hung, is fix'd to a flat wooden Cross, at the End of each Arm of which there is a Hook, serving to keep the Telescope from too much Agitation when the Instrument is using, and for keeping it steady when it is carrying, in lowering the Telescope, by Means of the Screw 3, which carries it.

THERE is apply'd to the said flat Cross another hollowed Cross, fasten'd with Hooks, which serves as a Case to the Instrument. But note, the two Ends of the Cross are left open, that so the Telescope being covered from Wind and Rain, may be always in a Condition to use.

THE Foot supporting the Instrument is a round Brass Plate, something concave, to which is fasten'd three Brass Ferrils, moveable by Means of Joints, where are Staves of a convenient Length put; the Box at the Bottom of the *Level* is plac'd upon this Plate, and may be any Ways turn'd, so that the Weight, which ought to be Brass, may have a free Motion in the Box, which must be shut by Means of a Screw, so that the Oil may be preserv'd in Journeys.

FIG. 8. Tab. seq. is the Representation of one of the best Kind of *Spirit-Levels* I know of, especially for the Use of Gardeners, if improv'd in the Manner I have there describ'd. The first that ever I saw of this Kind, was in the Hands of Mr. *Bridgeman*, now deservedly advanc'd to be one of His Majesty's Gardeners.

It may be made from two Foot, to two Foot and a half, or three Foot long, of any season'd Piece of Oak, or other Wood, about three Inches wide, having Sights framed on at a a. In the Middle at X there is (according to my Design) a Pin, on which the Rule b b turns; and round the Center is a Convex-Glass, with Circles drawn round it, as on the Plan, which Circles are so exactly level, that whenever the frigid Liquor which is put in stands to a true Level, it touches one or other of these Circles, or so near to it, that you may discover when the Instrument is level. To make this more perfect, I have added a Tube at each End, which runs towards the Sights, as in other *Spirit-Levels*, which Tube is also join'd cross-ways to the Convex-Glass, and shews when the *Level* is right that Way; so that having taken your View one Way, you may, by the Help of the cross Rule b b, take any other *Level*, whether diagonal, square, or otherwise,

otherwise, without moving your Instrument again, or altering the first *Level*.

ON the Edges of the Circle, you may have Degrees divided (if you please) according to the Degrees of a Circle, which will be of Use to any Gardener likewise in the setting out his Walks, and taking of Levels, and is, in short, so universal an Instrument for his Use, that (if well made) I can't think any equal to it.

A Box and Needle may be also fix'd to it at the *Fleur-de-Lis*; and the Whole, if it falls into the Hands of one Artist, may be made of the greatest Use. All this may be done on a plain Table.

FOR the Rectification of all Levels, (that I may explain myself the better,) take the following Account, as I find it in *Le Bion*, *Vid. Fig. 10. Tab. seq.* Plant your two Staves at A B, about fifty Toises Distance from each other, because of the Roundness of the Earth you must not exceed that; then espying from the Station A the Point B, the Level being plac'd horizontally, and the Bubble of Air being in the Middle of the Tube, you must raise or lower a Piece of Paste-Board or Vane upon the Staff B, (in the Middle of which, as *Vid. B. Fig. 12. Tab. seq.* there is an Horizontal Line,) till the visual Ray of the Observer's Eye meets the said Line; after which fix another Piece of Paste-Board to another Staff of the same Division, which we call A, the Middle of which let be the Height of the Center of the Paste-Board; and the Level being horizontally plac'd for observing the Vane or Paste-Board A; if then the visual Ray cuts the Middle of the Piece of Paste-Board, it is a Sign that the Level is very just; but if the visual Ray falls above or below, as in the Point C, you must, by always keeping the Eye at the same Height, lower the Telescope, or the Sight, till the Middle of the visual Ray falls upon the Middle of the Difference, as in D; and the Telescope thus remaining, the Tube of the Level must be adjusted, till the Bubble, either of Air, Quick-silver, or Spirit of Wine, fixes in the Middle; which is done by Means of a Screw fix'd at the Bottom of all Levels, for that Purpose. Again return to the Staff A, and place the Level to the Height of the Point D; and looking at the Vane or Paste-Board B, if the visual Rays fall on the Middle of the Piece of Paste-Board, it is a Sign the Telescope or Sight agrees with the Level; if not, the same Operations must be repeated, until the visual Rays fall upon the Centers of the two Pieces of Paste-Board. And thus, with what is set down in other Places, you have full Instructions for rectifying any Instrument.

THE next, and which is, I think, a very genteel and ingenious Instrument, is the Telescope *Spirit-Level*: The Invention,

as I take it, (for I am not, as yet, well acquainted with that Gentleman,) of *William Sisson*, at the Corner of *Beauford-Buildings*, in the *Strand*, being of great Use for those who are to take the Dependance of a River, (or any other long Length,) for Navigation, or otherwise, be it fifteen or sixteen Miles, or sometimes more.

THIS Instrument consists of a Brass Telescope, of a convenient Length, the longer the better, provided, the Parts of the Instrument, which support it, be proportionably strong. Within this Telescope is fix'd a Hair, and a small Micrometer, whereby the Distances may be determined at one Station near enough for the Business of Levelling; upon this Telescope is fix'd, with two small Screws, the Spirit Tube, and Bubble therein, which Bubble will rest exactly in the Middle of the Tube, when the Telescope is set truly level.

UNDER the Telescope is a double Spring, with two Screws, by which the Bubble is brought exactly to a Mark in the middle of the Tube; to which Spring is fix'd a Conical Ferril, which is a Direction for the Telescope to move horizontally at Pleasure. There is also a three-legged Staff, a Ball, Socket, and four Screws, to adjust the Horizontal Motion, the same with that belonging to all surveying Instruments.

FOR your Assistance to this, and the other Levels before mentioned, you are to provide two Station Staves, (for one whereof *See Fig. 12. Tab. seq.*) each ten Foot long, that may slide one by the Side of the other, to five Foot, for easier Carriage; let them be divided into 1000 equal Parts, and number'd at every tenth Division, 10, 20, 30, 40, &c. to 100, and from 100, 110, 120, &c. to 200, and so on till you come to 1000; but every Centesimal Division, (which is the most as can be express'd in the Figure before mentioned,) as 100, 200, 300, &c. to 1000, ought to be express'd in large Figures, that the Division may be more easily counted; and you may have another Piece five Foot long, divided also into 500 equal Parts, to be added to the former, when there shall be Occasion.

UPON these Staves are two Vanes, or black Boards, made to slide up and down, which will also stand against any Division on the Staff, by the Help of Springs; these Vanes are best made thirty Parts wide, and ninety Parts long; let the Faces of them be divided into three equal Spaces, by two Lines drawn Length-ways; let the two extream Parts be painted white, and the other two black, which will render them fit for all Distances.

BEING thus provided with a good Instrument, two Station Staves, a Chain, and two Assistants, you may proceed to your Work; but first

first it will be necessary to know if your Instrument be well adjusted.

Now to do this, you are to chuse some Field or Meadow, which is nearly level, and set down the Instrument about the Middle thereof, and make a Hole in the Ground, under the Center of the Instrument; from which measure out a right Line, some convenient Length, as twenty Chains, and there leave one of your Assistants with his Station-Staff; and then return to the Instrument, and measure out the same Number of Chains, *viz.* twenty, the other Way, by the Direction of the Instrument and last Station-Staff, as near in a right Line as you can guess, and there leave your other Assistant with his Station-Staff; so will the Instrument and two Station-Staves be in the same Line.

THEN return to the Instrument, and set it Horizontal, which is presently done by the Ball and Socket, and turn the Telescope about on its Horizontal Motion to your first Assistant, and move the Telescope by the two Screws in the double Spring, till the Bubble rests exactly in the middle of the Spirit-Tube; then observe where the Hair cuts the Staff, and direct your Assistant to move or slip the Vane or Board up or down, till the Hair cuts the Middle thereof, so that you may see as much of the Vane above the Hair as below it, and there give him a Sign to fix it; then direct the Telescope towards your second Assistant, and proceed in the same Manner; so are the Vanes on each Staff equidistant from the Center of the Earth.

REMOVE the Instrument to that Assistant which is nearest the Sun, if it shines, that you may have the Advantage of its Rays upon the other Assistant's Vane, and there set down the Instrument as near the Staff as you can; then having set the Instrument Horizontal, so that the Bubble rests in the middle of the Tube, observe what Direction is then cut by the Hair in the Telescope, above or below the middle of the flat Board or Vane; for so many Divisions must the other Assistant's Vane be elevated, or depress'd, which you must direct him to do accordingly.

HERE the Distance of the Instrument, from the Station-Staff, is forty Chains, for which you must make an Allowance for the Earth's Curvature, which, by the Table, which will be produc'd in one of the next Pages, you will find to be $16 \frac{6}{10}$ Parts, therefore let the Vane on the Staff be rais'd $16 \frac{1}{2}$ Parts.

Now direct the Telescope to the Vane thus rais'd, and if the Hair cuts the Middle thereof, whilst the Bubble rests in the Middle of the Tube, the Instrument is right; but if not, then you must raise

raise or deprefs the Telescope by the Screws in the double Spring, till the Hair cuts the Middle of the Vane; and then, by the Help of the Screws that fix'd the Tube to the Telescope, move the Bubble till it rests in the Middle of the Tube; so is the Level adjusted.

As to the Allowances to be made for the Curvature of the Earth, when the Station-Staves are planted at unequal Distances from the Instrument, you must take the following Method:

SUPPOSE the Instrument was plac'd on an Eminence, between the two Valleys a and b, *Fig. 11. Tab. seq.* and the first Assistant standing with his Station at c, and the second at d, and it is required to know the different Height of the Hills c and d.

FIRST set the Instrument Horizontal; and then direct the Telescope to the first Assistant's Staff at c, and by the Spring-Screws set the Bubble exact, observing where the Hair cuts the Staff, and by Signs cause him to move the Vane higher or lower, till the Hair cuts the Middle thereof; and then give him a Sign to note down the Division cut by the upper Edge of the Vane, which suppose 104 Parts from the Ground, and by the Micrometer in the Telescope, I find the Distance, from the Instrument to the Staff at c, to be about ten Chains.

THEN I direct the Telescope to d, and proceed in the same Manner as before, and find that the Hair cuts 849 Parts from the Ground, and by the Micrometer the Distance to d, is determin'd to be about thirty five Chains.

NEXT I look into the Table of Curvature following, and find against ten Chains, one Part to be deducted for the Curvature of the Earth at that Distance, so will the Assistant's Note be made 103 Parts.

ALSO against thirty five Chains, I find $\frac{7}{1210}$, which being deducted out of 849, there remains $836 \frac{3}{10}$ Parts which must be noted by the second Assistant.

Now if 103, as noted by the first Assistant be subtracted from $836 \frac{3}{10}$, as noted by the second, the Remainder will be $733 \frac{3}{10}$, and so much the Hill c is higher than the Hill d.

If the Spring-Head, or Conduit-house Q, be on the Precipice of a Hill, you must make a very short Level H to F, by a very tall Pole plac'd at c, which Pole let remain till you have mov'd your Instrument to R, at which Time you may turn your View backwards and forwards both to G and D. But to proceed:

Here

96 *An Introduction to a General System*

Here follows a Table of the Earth's Curvature, calculated to the Thousandth Part of a Foot, at the End of every Chain, from one Chain to forty.

Chains.	Dec. feet.	Chains.	Dec. feet.	Chains.	Dec. feet.	Chains.	Dec. feet.
1	000	11	013	21	046	31	099
2	000	12	015	22	050	32	106
3	001	13	017	23	055	33	113
4	002	14	020	24	060	34	120
5	003	15	023	25	065	35	127
6	004	16	026	26	070	36	134
7	005	17	030	27	075	37	141
8	007	18	033	28	081	38	149
9	008	19	037	29	087	39	157
10	010	20	041	30	093	40	166

THUS you have a Table of the Curvature of the Earth ; but if the Table is not at hand, or the Number requir'd be not to be found therein, then you may find the Allowance which is to be made at any Distance, by the following Rule :

MULTIPLY the Square of the Distance in Chains by 31, and divide the Product by 300000, you will have the Answer.

IN this Manner making Allowance for the Curvature of the Earth, you may send a Station-Staff forwards half a Mile, or farther from the Instrument, and take a Sight over Valleys at once, the Horizontal Distance being, in this Case, the only Thing to be regarded.

THUS much of the general Uses of the Levelling Instruments before mentioned, Curvature of the Earth, &c. But before I proceed to that which is more particular, I mean the Operation itself, the Method of noting down in the Field such Observations as shall occur, (according to my Promise,) I shall give an Account of a very extraordinary Instrument, contriv'd by Mr. *Thomas Heath*, Mathematical Instrument-Maker, next Door to the *Fountain-Tavern* in the *Strand*, a Person who, for Curiousness of Invention and Workmanship, (being himself a through Mathematician,) equals, if not excels, any of his Profession.

THIS

THIS Instrument consists of a Brass Circle or Limb AA, *Vid. Tab. seq.* ten Inches in Diameter, or any other Size at Pleasure, divided into 360 Degrees, and an Arch of it is divided into Parts, figured each Way ten, twenty, thirty, &c. to ninety, being mark'd Feet, and are for taking the Perspective of a Building, upon which are two fixed Sights bb, for viewing Objects that are near, or when the Instrument is using in hazy Weather, when they cannot be distinctly seen through a Telescope. This Limb is fix'd upon a Brass Pillar or Cylinder, having a Ball at the Bottom of it, that goes into a Socket made in the Middle of the round Plate GG, so that by Means of the Ball and Socket: The Plan of the Limb AA may be set to a requir'd Position or Inclination, with respect to the Plane of the Circle GG, and may be kept to that Position by Means of a Screw and Worm underneath the Plate GG; the circular Plate BB is fixed upon the aforesaid Pillar or Neck of the Ball, having its Plane parallel to the Plane of the Limb AA, and has four Screws in it; the Worms of which pressing against the circular Plate GG, are for setting the Plane of the Limb AA level or parallel to the Horizon, by Means of a little Spirit Air-Level ff, fixed to the Top of the Telescope EE, that so the Instrument may serve as a Quadrant, in taking the Quantity of Degrees of an Altitude, and likewise for other Uses hereafter mentioned. The Plate a a a a, called the Index, is moveable about the Centre of the Limb AA, and the Arches of the two opposite Pieces of it, or Ends of the Index, rest upon the Limb, in order to take the Quantity of Degrees of an Angle, contain each thirteen Degrees of the Limb; which Arches are each divided into twelve Parts, and figur'd 10, 20, 30, 40, 50, 60, that so the Quantity of an Angle may be taken to 5 Minutes. This Index has a Box and Needle cc fixed upon it, and near the aforesaid Ends of the Index, are plac'd perpendicularly two similar and equal vertical Arches cc, cc, of about thirty nine Degrees each, which are joined to the cross Piece DD supporting the Centre, about which a Telescope EE moves. This Telescope carries four perpendicular or vertical Sights e, e, e, e, for viewing Objects in hazy Weather, or that are near; as likewise two Pieces upon the Arches cc, cc, serving as an Index; which Pieces each contain an Arch of thirteen Degrees of the Arches cc, cc, being each divided as the Ends of the Index a a a a were, that so the Quantity of an Angle of Altitude may be taken to five Minutes. These Arches cc, cc, contain three Scales of concentrick Divisions, mark'd *De, Li, Fe*, the first being Degrees, the second Links, and the third Feet, the former giving by the Thread of the Middle of the Index the Degrees of the

O

Altitude

Altitude or Depression of an Object, if not exceeding thirty nine; the other the Number of Links in every Chain's Length, at that Angle of Altitude or Depression that are to be taken from, or added to the Hypothenufal Line of one Chain, in order to have the horizontal Line, by which Means the horizontal Line of an Hill will be very exactly obtained; and, lastly, the third, the Height or Depth of an Object in Feet, when the Instrument stands at 100 Feet Distance from it.

AT the Letter p there is a little Pin fasten'd to the Telescope, which is for keeping the Telescope and Index such, that its Line of Collimation be parallel to the Plane of the Limb.

FINALLY, the three Legs of the Instrument screw into three Brass Pieces, which constitute a Triangle, and are fasten'd underneath the circular Plate G G, and open and shut at Pleasure, and may be unscrew'd in the Middle, that so their Length being diminish'd by one half, they are render'd more portable.

N. B. The Centre, about which the Index a a a a moves, and upon which the Needle hangs, is fix'd to the Plate A A, that so when the Index is moving, the Needle is not thereby disturbed.

THIS general and most curious Instrument of Mr. *Heath's* (with others before mentioned) being thus describ'd, let us now come to the Operation it self, in which it is requir'd to know whether Water may be convey'd in Pipes or Trenches from a Spring-head to any determin'd Place.

AT the Spring-head set up one of your two Station-Staves, as nearly perpendicular as you can, and leave with one (whom you may call your first Assistant) proper Directions for raising or depressing the Vane on his Staff, according to certain Signs which you (standing at your Instrument) shall give him. Also let him be provided with Pen, Ink, and Paper, to note down very carefully the Division of the Staff which the Vane shall cut when you make a Sign that it stands in its right Position.

CARRY your Instrument toward the determined Place you are going to, as far as you can see, so that through the Telescope you may but see any Part of the Staff left behind when the Instrument is set horizontal; and from that Place send your second Assistant forward with his Station-Staff, with the same Instructions which you gave your first.

SET the Instrument horizontal, by the Help of the Ball, Socket, and Screws; and direct the Telescope to your first Assistant's Staff, and then by the help of the Spring-Screws bring the Bubble exactly to the Middle of the Tube, and when it rests there give a Sign for your Assistant to note the Parts of the Staff.

Now

TURN about the Telescope to your second Assistant's Staff, and by the Spring-Screws, as before, set the Bubble exact; then direct your second Assistant to move the Vane higher or lower, till you see the Hair in the Telescope cuts the Middle of the Vane or Sight-Board, (but in long Distances the Hair will almost cover the Vane, however, let it be set in such a Manner that as much may be above the Hair as below it, as near as you can guess,) and then give him a Sign to note the Division on the Staff; and always let your Assistants note the Division cut by the upper Edge of the Vane.

LET your first Assistant then bring his Station-Staff from the Spring-head, and changing Places with the second Assistant, let your second Assistant carry his forwards to the determin'd Place to which you are going, and at a convenient Distance erect it perpendicular, whilst your first Assistant carries with his Staff where your second Assistant stood before.

PLACE your Instrument between your two Assistants, as near the Middle as you can, (on Account of the Curvature of the Earth,) and first direct your Telescope to your first Assistant's Staff, and when the Telescope is levell'd to one of the Divisions on the Staff, let him note that Division in an orderly Manner under the first Observation; and let the second Assistant do the same. And in this Manner proceed over Hill and Dale, as strait forwards as the Way will permit, to the appointed Place, (only repeating those Directions,) though it be twenty Miles Distance from the Spring-head. But in your whole Passage let this be a constant Rule, from which you must never depart, *viz.* that your first Assistant must at every Station stand between the Spring-head and your Instrument, and your second Assistant must always stand between the Instrument and the appointed Place to which the Water is to be convey'd; and also the first Assistant must be sure to place his Staff exactly in the Place where the second stood.

BEING come to the Place appointed, let both your Assistants give in their Notes, which ought to stand in Manner and Form following:

First Assistant's Notes.		Second Assistant's Notes.	
Stations.	Parts.	Stations.	Parts.
1	1029	1	1325
2	529	2	634
3	695	3	743
4	793	4	898
5	821	5	762
6	1378	6	1354
7	724	7	891
8	227	8	1149
9	465	9	532
10	732	10	891
11	321	11	654
12	621	12	1531
Sum	8335	Sum	11364

When you have taken the Levels, and summ'd up the same, you will find the Difference of the two Assistant's Notes to be 3029 Parts, which is about thirty Foot $\frac{1}{3}$. But that you may be the more certain, it is best to try the same in another Track, and by another good Instrument, and if it may happen to be the same, which it will nearly be, if the same is rightly survey'd. Of this I once made an Experiment, and the Accounts of my two Assistants stood as in the following Table. Where note, that though in the second Experiment there were more Stations, and a much greater Variety of Ground than there was in the first, by which Means there was a greater Number, yet by these Notes added together, as before directed, and compar'd with the other Table, you will see the Difference is but 28 Parts; which is inconsiderable, considering the Number of Stations, and the Unevenness of this last Survey.

First Assistant's Notes.		Second Assistant's Notes.	
Stations.	Parts.	Stations.	Parts.
1	514	1	622
2	321	2	654
3	732	3	891
4	508	4	660
5	695	5	743
6	821	6	762
7	724	7	891
8	460	8	540
9	113	9	574
10	089	10	536
11	110	11	560
12	089	12	510
13	429	13	534
14	198	14	200
15	097	15	100
Sum	5900	Sum	8777

NOTE, If from the first Assistant's Staff you measure any Number of Chains towards the Place you are going to, as suppose twenty, and there set down the Instrument, and then measure ten Chains forwarder, and there place the other Station-Staff, you will have no Occasion to make any Allowance for the Curvature of the Earth, because the Instrument being planted in the Middle of the Distances between the Station-Staves, the Errors mutually destroy each other.

BUT this Measuring of the Distances with the Chain or otherwise, is very tedious, and in some Places (where the Ground is very uneven) unpracticable, unless you make a Multitude of Stations; so if the Way between the two determined Places, whose different Heights you would know, lies over Hills and Dales, as *Fig. 3. Tab. seq.* then you must, in that Case, make four or five Stations, (otherwise you will

will not be able to see any Part of the Staff when the Instrument is set horizontal,) which might as well be done alone, (as in the foregoing Observations,) in the Manner describ'd in the Table of Curvatures.

IN the Beginning of this Chapter, Mention was made of an old plain Water-Level, us'd by our Water Meadow-Men, some Account of which, (or very near it,) I remember to have seen in the Beginning of *Blythe's Husbandry*, which Instrument, and its Uses, in making Trenches, I would recommend before any other yet named, if you can keep a little out of the Wind. *Vid. Fig. 13. Tab. seq.*

LET A B be the Section of a new Cut, made for the conducting of Water to any Place, and C C D the Top of the Level, which has two Sights fram'd on, as f, g, and two Iron Rods, as h, i, going through the Middle of the Level near C and D, which are so put in, that they will easily admit of the Levels rising or sinking, by either of the Screws K, L.

THIS Level (being of the dryest Oak, three Inches square) ought to be six or eight Foot at least in Length, (the longer the better) in the middle of the Top of which let there be a Channel or Trough made, such as is us'd to be for Chickens to eat their Meat out of, and as is describ'd in *Fig. 14. Plate 3.* about an Inch, or an Inch and Quarter over, having at each End a square Well, into which the Water shall fall, whereby its Level may be the more conspicuous and plain. And with this we did my Lord *Coningsby's* Trench to a very great Truth.

C H A P. VII.

Of the proper Methods to be taken in the adjusting the Levels or Falls from a Spring-Head, so as to conduct them by a gradual Descent to the House, or other Place required.

THE Descent from the Spring-head to the Reservoir being taken, as directed in the last Chapter, the next Thing to be done is the determining what Fall the Water is to have, or, in other Words, how many Feet or Inches, or how much Dependance is to be allowed to a Yard, to a Pole, or to a hundred Feet or Yards, or a Mile or Miles, in Proportion, so as that the Water may have a proper Current, and may at last not fall too low, but be brought gradually to the Top of the Reservoir or Pond, where it is to be used.

BUT

YET before we proceed far into this necessary Adjustment of the Dependance or Fall of Water, it will not be improper to enquire into the Fall of some Aqueducts and Water-Courses, both at Home and Abroad, since 'tis from Fact rather than from Theory and Speculation we must deduce the most certain Consequences in this or any other Employ.

Vitruvius, Lib. 8. Cap. 6. as hinted at in the last Chapter, writes, "That the *Romans* allow'd for the Channels or Sewers of their "Aqueducts, for every Hundred Foot, running half a Foot of "Declination or Sloping, (which is near Twenty seven Foot "in a Mile, and if any Hills were in their Way, they dug "through them, making Vents to give Air at convenient Distances, "not being appriz'd in that early Dawn of Hydrostaticks, that if you "would confine your Spring in Leaden Pipes, it would (as the Reverend Dr. *Desaguliers*, in his *Elements of Natural Philosophy*, has "it) rise over Hill and Dale, if the Spring-head were so high as to "over-top them, proper Allowance being made for Friction, and the "Interposition of Air;" which may be let out by Wind-Cocks, as some Authors have taught.

THE so-much-fam'd Aqueduct of *Claudius*, as is also before set down, was (as the ever memorable Mr. *Addison* informs us, in his Travels into *Italy*,) five Foot and a half in a Mile, but whether that ingenious Gentleman means *Italian* or *English* Miles, does not so plainly appear; but if the latter, Experience tells us it is an Allowance large enough, even though it were not to be above a Foot Fall in a Thousand.

Varennius, in his *Geograph. General. Prop. xxvi. Pag. 268.* relates from some *French* Writers, That the *Seine*, out of which the Water is carried from the Armory at *Paris* to the Royal Garden, is scarce one Foot Fall in Five Hundred Fathom, every Fathom being six Foot; now 500 being multiply'd by six, the Produce is 3000 Foot, which is half a Mile, and 260 Foot if accounted in the *English* Way, by which it appears, that that Fall is about two Foot in a Mile: But later Experience tells us, that Water will descend in less than that.

THE Water-Course at *Plymouth* is, as I am inform'd, but five Inches in a Mile Fall; and that which I made some Years since for the Earl of *Coningsby*, is about four. The new River, as I am inform'd by my ingenious Acquaintance Mr. *Mills*, now chief Surveyor of that Work, who took it at several Places with great Care, is, in the Mean, but between three or four Inches Fall in a Mile; though in some Places it is more, others less: And I remember to have read

104 *An Introduction to a General System*

some time since in some of Sir *Jonas Moore's* Works, that he allow'd but three Inches; and the same is practis'd in the Fenns of *Lincoln* and *Cambridge* Shires, where the Water is almost on a deadish Flat; but the general Allowance is four Inches and a half by all Engineers.

To conclude this, The conducting of Water varies according to the Conveyances in which you carry it. Water conveyed in Pipes, especially if they are small, requires more Dependance than any other Way, on the Account of the Friction that there is against the Sides of the Pipes, as well as the Wind-boundedness that is generally therein, of which more is said elsewhere. That which is convey'd in Drains, will pass more easily and free; but Water passing in an open Carriage, will pass the freest of all, except the Winds are against the Stream, because of that continual Agitation and Impulse that there is in the Air. But of this more in another Place.

BUT to come to Practice: Suppose that the Length you are to convey the Water is 1000 Yards, and the Fall from the Spring-head to the Reservoir or House is twenty five Foot nine Inches, and it should be required to know how many Inches, or Parts of an Inch, must be given to every Yard or Pole, in order to give this Water its proper and gradual Descent or Fall.

IN the first Place, you are to turn the twenty five Foot nine Inches into Inches, which makes 309; but that not being reduc'd into Terms low enough to be divided, divide by the 1000, the 309 must be again multiply'd by 12, to bring it into Lines or Parts of an Inch, the Produce of which is 3708, as is seen in the Example.

F. In.	
25 : 9	
12 : 0	

300 : 0	
9 : 0	

309 : 0	
12 : 0	

3708 : 0	

WHICH being divided by 1000, the Number of Yards contained in the Length, the Quotient will be three Lines $\frac{708}{1000}$ of a Line, which is near 3 Lines $\frac{3}{4}$, or a Quarter and $\frac{3}{4}$ of an Inch; however, you may give it a Quarter and half Quarter,, which is four Foot seven Inches in a Mile, and have to spare and to answer for any Error

Error or small Mistake that may happen in the Execution of the said Work.

SUPPOSE farther, that the Length of this Fall of twenty five Feet nine Inches, be four Miles and a Quarter, and it is requir'd to know how many Feet or Inches it is proper to allow in a Mile, or any Part or Quantity of a Mile.

FIRST reduce the four Miles and a Quarter into Quarters of a Mile, which making nine by such Multiplication, divide the twenty five Feet nine Inches by nine, and the Quotient is the Answer.

EXAMPLE.

	Fe.	In.
	25	: 9
	12	: 0
9)	309	: 0 (34 $\frac{1}{3}$
	39	: 0
	34	: 3

AND the Answer is $34\frac{1}{3}$ or 2 Foot 10 Inches $\frac{1}{3}$, and so much must be allowed for the Fall in a Quarter of a Mile, which is one Foot five Inches in a Furlong, and a little more than one Line or one twelfth of an Inch to a Pole, and eleven Foot and a half in a whole Mile a very good Dependance for the Passage and Conveyance of Water where it can be had.

BUT there are other Things to be considered, in relation to the Conveyance of Water in Pipes, I mean those of Friction, Wind-boundness, &c. because as *Marriot* and his Reverend Translator observe, (and that from curious Experiments,) that Water never rises to its own Level, on Account of the Friction that is on the Sides of the Pipes, which Friction increases the longer the Distance is.

Now to adjust this Stoppage or Friction as near as may be, the general Rule amongst Workmen is to allow one Eighth of the Height for the Interruption or Hindrance it meets with in its long Passage.

So that if the Descent from a Spring-head to the Reservoir be 128 Foot, you are, according to this general Rule, to divide it by eight, and the Produce will be sixteen; which shews that the Water will not rise so high as the Spring-head by sixteen Foot.

BUT Monsieur *Marriot* (to whom so much is owing for his Experiments in Hydrostaticks,) has brought this Matter to a more exact Calculation, producing it as a certain general Rule, that *the Difference of the Height in Jets*, or he might have said in other Words

106 *An Introduction to a General System*

the Descent of the Water from its Head to the Reservoir or Place assigned for the Reception of it, is in a Subduplicate Ratio of its Height; and though 'tis certain that that ingenious Gentleman made use of this Rule to demonstrate the Rise of Jets in open Air, and as external Air has undoubtedly a greater Effect on the Rise of Water, than the Friction against the Sides of the Pipes, we may be the more sure, that if there be any Error, it is on the right Side, and that, without any great Deviation from Truth, it may be applied to the Friction, that is in enclos'd Pipes.

BUT to proceed upon the Foot of the foregoing Rule, it is, as may be seen *Pag. 270.* of *Dr. Desaguliers's* Translation, and which is confirm'd by undoubted Experiments, that a Spring-head five Foot one Inch high, will raise the Water five Foot, and that consequently the Friction that is allow'd is one Inch; and according to this Proportion the following Table is calculated.

A Table of the Heights to which Water will rise, proceeding from Reservoirs or Spring-heads of different Heights; as also from five Foot to one hundred.

Height of the Reservoir or Spring-head.		The Height to which Water will rise.	
Feet.	Inch.	Feet.	Inch.
5	1	5	0
10	4	10	0
15	9	15	0
21	4	20	0
27	1	25	0
33	0	30	0
39	1	35	1
45	4	40	0
51	9	45	0
58	4	50	0
65	1	55	0
72	0	60	6
79	1	65	0
86	4	70	6
93	9	75	0
101	4	80	0
109	1	85	0
117	0	90	0
125	1	95	0
133	4	100	0

It has before been observed, that the Weakness of Water that runs a great Way, is a great deal more in Proportion to the Length it runs, than to any other Cause, it being found by Experiments, (as the learned and industrious Dr. *Desaguliers* has it,) that this Diminution or Weakening of the Water diminishes rather in Proportion to the Length it runs, than to the Friction against the Sides of the Pipes.

BUT as this Diminution is Fact, (let it proceed from what Cause it will,) and as all Motions decrease in Proportion to the Spaces through which they pass, it may not be improper, before we quit this Chapter, to endeavour at its Determination as near as possibly we can, that we may come the nearer to the Truth of our Calculation, in the giving this requisite Dependence to Water that is to run from a Spring-head to the Reservoir (as before) in Leaden or other Pipes.

AND since this Diminution or Stoppage is (as all other Motions are) in a subduplicate Ratio to the respective Spaces through which it passes, let us suppose, that, as Water that falls from a Reservoir of 133 Foot high, rises but to 100 Foot at 1000 Yards Distance, and that this Diminution beginning from thence increases gradually, suppose four Inches at the first, and so on, according to the aforementioned *Ratio*, then the Account may stand thus :

A Table of the Diminution or Decrease of Water passing through Pipes of great Lengths.

Length. Yards.	Decrease.	
	Feet	Inch.
1000	0	4
1500	0	9
2000	1	4
2500	2	1
3000	3	0
3500	4	1
4000	5	4
4500	6	9
5000	8	4
5500	10	1
6000	12	0
6500	14	1
7000	16	4
7500	18	9
8000	21	4
8500	23	1
9000	27	0
9500	30	1
10000	33	4

By which it appears, that this Diminution will be thirty three Feet four Inches in 10000 Yards, or about five Miles and three Quarters, or something more. And this seems to be the least that can be allow'd; so that were we to make an exact Calculation from these Rules for the Descent of Water, the four Miles and a half in Length before mentioned, it would come to agree pretty nearly with what I have been thus endeavouring to establish for a certain Rule, which will be visible from the Example following, which is summ'd up in two Lines.

	Fe.	In.
<i>Imprimis</i> , The Friction of 25 Feet 4 Inches about	2	: 2
<i>Secondly</i> , The Diminution or Decrease in passing through 8000 Yards, which is a little more than four Miles and a half,	21	: 4
	In all	23 : 6

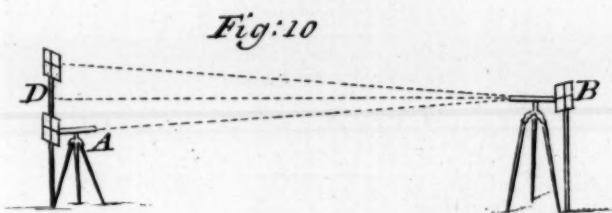
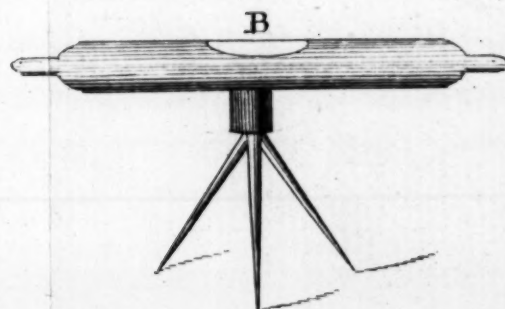
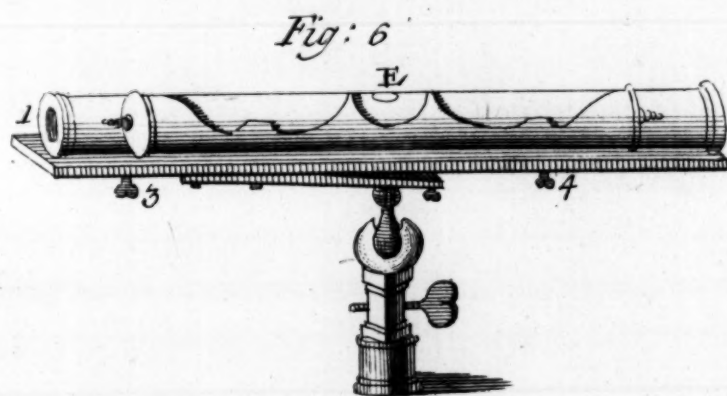
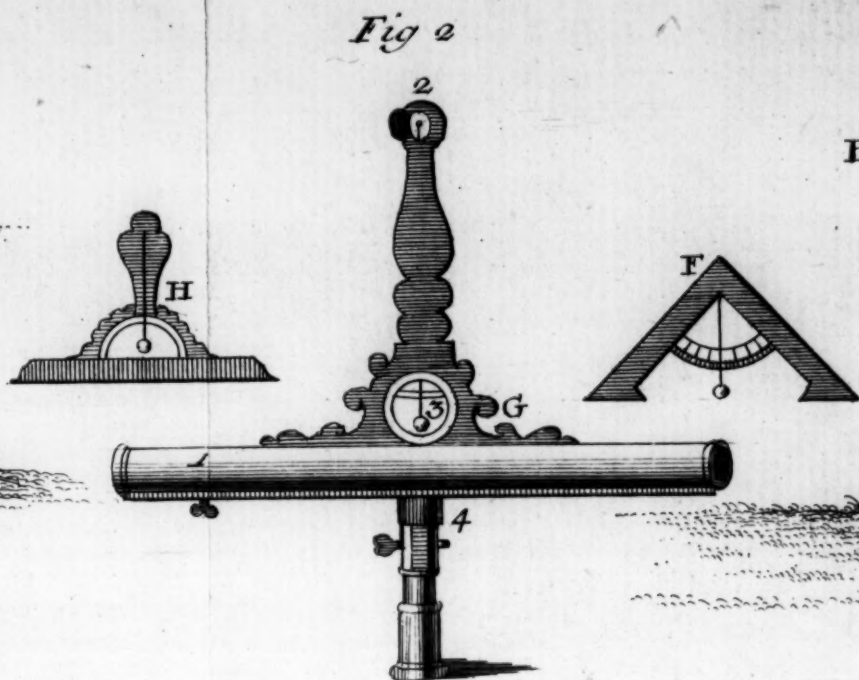
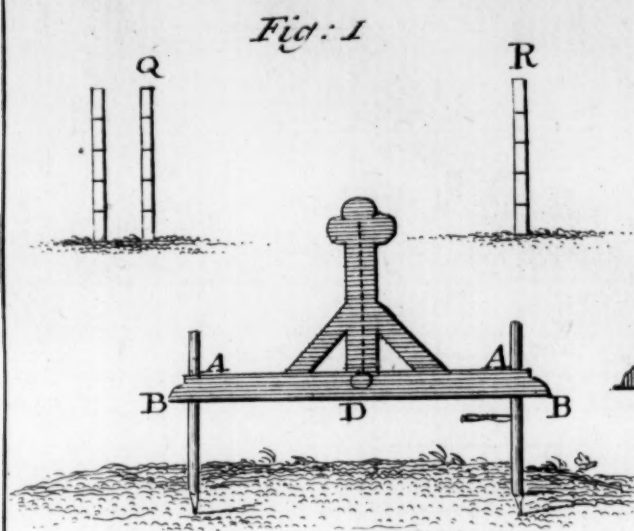
BUT notwithstanding what has been said of this * Diminution or Stoppage in Pipes of Conduct, yet in large open Aqueducts, Rivers, or Sewers, (where the Friction is not sensible,) there will be no Occasion for this great Care in the Calculation of this Dependance in Water.

IT is apparent from what has been before advanc'd, that one Foot in a Mile is Dependance large enough for any River, Aqueduct, or the like; it being a considerable Rule in Hydrostaticks, that the larger the Aqueduct or Pipe of Conduct is, the less is the Friction, which may be so enlarg'd as not to be sensible at all.

THESE Things being premis'd, and in such a plain Manner, that the Conductor of Springs may see if he is like to run into an Error, by attempting at that which it will be impossible for him to perfect by natural Means, the next Thing requir'd is the Proceeding on with the Work.

WHEN you are to convey Water for about 1000 Yards, and have from the foregoing Rules known how much Fall it is proper to give in a Yard, as is set down in the Example at the Beginning of this Chapter, *viz.* a Quarter of an Inch, if you proceed by the Garden Level and ten Foot Rod, which is as good a Method as any: Let your Level be a little above ten Foot long, and exactly at the ten Foot nail on a Piece of

* What I would endeavour to establish from these Rules, is, that though Water in an open Sewer or Drain may pass at four, five, or six Inches in a Mile Fall, yet if it be to pass through Pipes of Conduct you can't allow it less than five Foot Fall; and so the Aqueducts of *Rome* are, as is before observed. I will not positively say, that Water won't pass at all in a less Allowance, because I have not had Experience of it; but I will venture to say it will pass freely, which is the same Thing.



Heaths new Improved Theodilite and water Levell

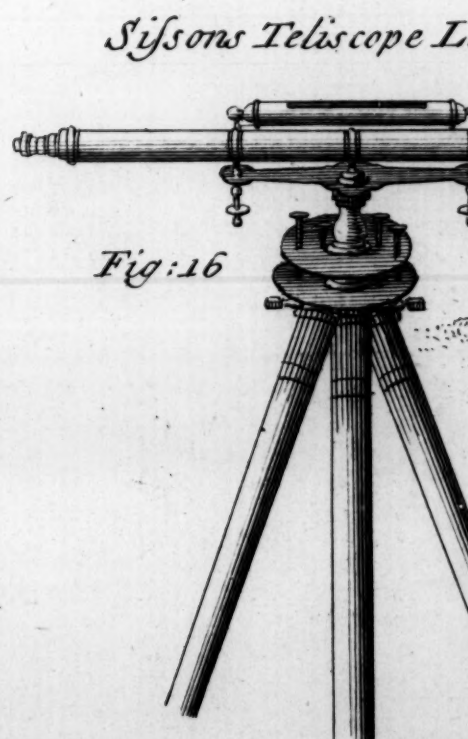
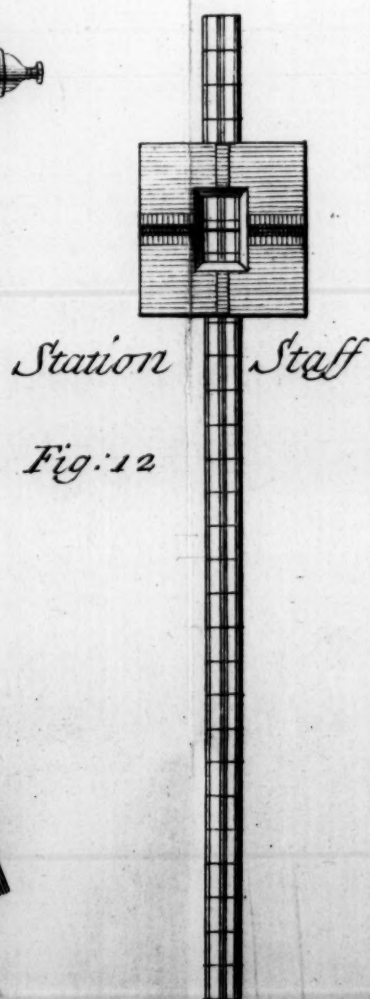
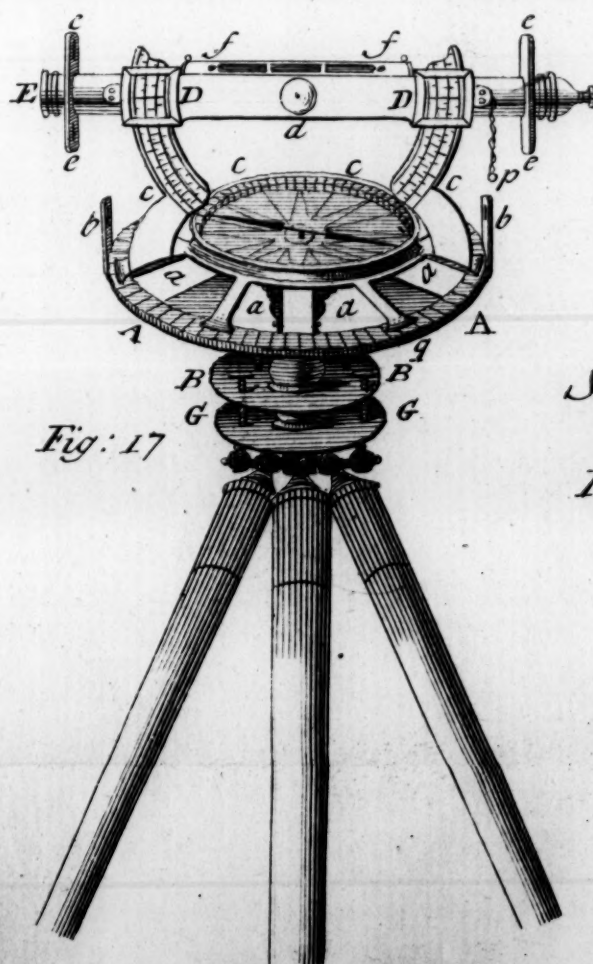


Fig: 3

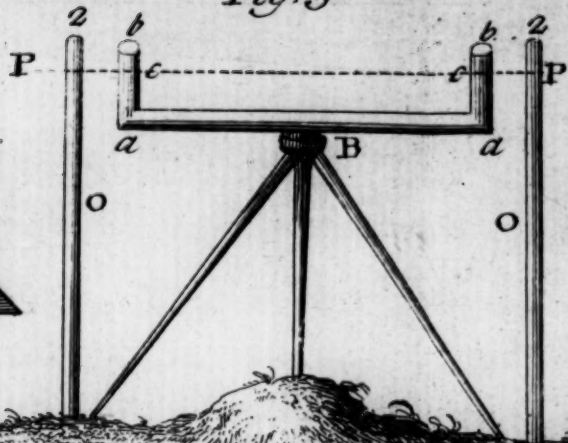


Fig: 4

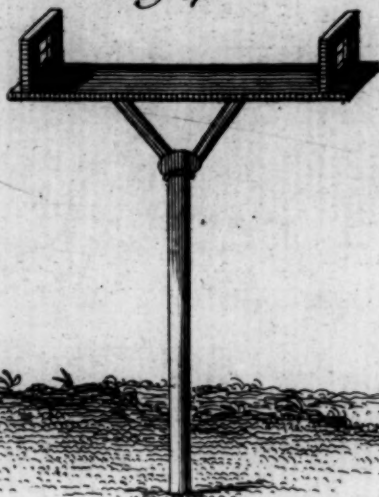
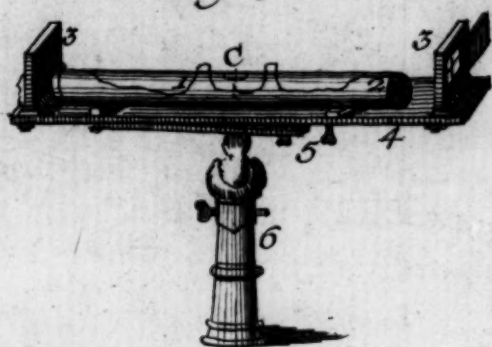


Fig: 5



The Improved plain table

Fig: 8

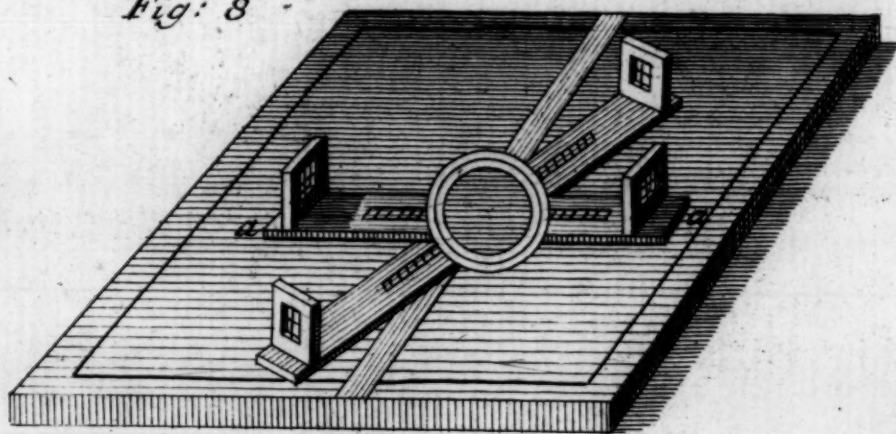


Fig: 7

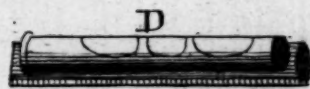
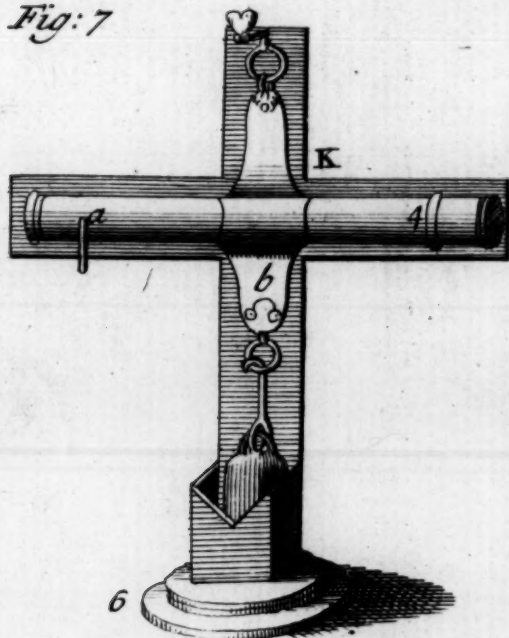
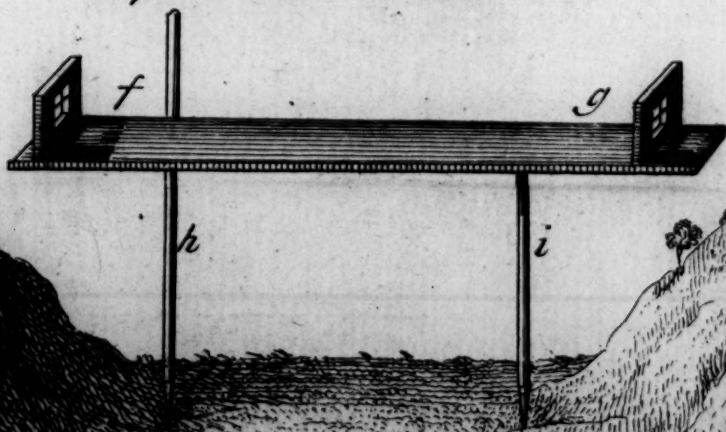


Fig: 15

scope Levell



Blythes water Levell



of Wood of $\frac{1}{4} \frac{1}{3}$ of an Inch thick, and beginning about a Foot or two below the common Surface of the Spring, as it is in the highest and best Seasons, or exactly at the Mark as it is in the lowest, keep that End of your Level on which the Piece of Wood is nailed always from the Spring, and that will give the first Dependance. You may if you please turn over the Level three or four times, and drive good square Stakes down so, as that they may remain some Time: And if you can see any great Length, you may with Boning-Staves, with which a good Workman ought always to be provided, bone quite through that View: But if you are oblig'd to go winding, then you must turn your Level over and over again, and your Level should be so conducted, as that the Stakes may stand just upon the Brow of the natural Ground, that your Pipe may not lie within above three Foot of the Surface; or if it be an open Sewer, you may not break up above two or three Foot, nor dig above two or three Foot deep in all Sideling Ground.

To effect the same by the Water or Spirit-Level, you are to stand at the Spring-head, and having turn'd your Instrument on the hanging Level, or, in other plainer Words, on the Hang of the Hill where the Water is to pass, let your Assistant set forwards with a ten Foot Pole or Rod in his Hand, and holding his Hand at about four or five Foot high, and let him move up and down the Hill till the Level exactly strikes the Assistant's Hand; and if you can carry it strait, let this be seventy, eighty, ninety, or 100 Yards, more or less, allowing the Quarter of an Inch to a Yard Fall, as is before specify'd, which suppose to be eighty Yards, you are to allow ten Inches lower to your Gauge-Stake, and bone in new Pins or Stakes at every fifteen Foot asunder; from which Gauge you are to dig your Cut three Foot deep to lay your Pipes in; or if it be a bank'd River or Sewer, you are to throw your Stuff in all Sideling Ground to the lowest Side, letting this Stake be in the Middle of your Cut, be it either of fifteen or twenty Foot, either of which are sufficient in Works of this Kind. But of this more in its proper Place.

WHAT I have to observe more on this Head, is, that you creep along the Side or Precipice of the Hill, if it be for an open Sewer or Drain, to be made of Brick or Stone, and be as exact as possibly you can in your Level; but if your Conveyance be of Leaden, Wooden, or Earthen Pipes, and the Spring lies so high as that you can command any Hills that lie between it and the House or Reservoir to which you are to carry it, and can by the Rules before going be sure you can carry the Water over them, you may go the nearest Way. Of which more in the next Chapter.

C H A P. VIII.

Of the conducting of Water by Aqueducts, Drains, &c.

Running Water conducted in Aqueducts is certainly to be preferred to Water rais'd by Engines, because Repairs, which hinder the coming in of Water, are not so often needed, and the Water may come easier and in greater Plenty than when it is rais'd by Engines, and is brought in by Pipes; besides, the Expence is generally larger, both in the doing it at first, as well as keeping it afterwards; and perhaps it had been cheaper, as well as better, for that great King of *France*, by whose Magnificence the Water-Works of *Versailles* and other Parts of *France* grew to such a stupendous Height, to have conducted the Water from the *Eure* to the Castle of *Versailles*, though it should have been twenty, thirty, or forty Leagues Distance from that Palace, than to have been at so extravagant an Expence, as he was in the Machine of *Marly*, and the costly Aqueducts that lead therefrom to *Versailles*; a Work so costly, that I remember to have read a small Treatise, writ by one of his own Officers, where, though in an absolute Monarchy, he dar'd to tax his Master with Profuseness and Extravagancy.

MOST of the Aqueducts of *Rome*, and some Water-Conveyances in *England*, are not a great deal short of the Distance that the *Eure* was from *Versailles*; and that great Prince was so sensible of his Errors, that Monsieur de *Louvois* employ'd the Editor of Monsieur *Marriot's* Hydrostaticks, as he tells us in the Preface thereto, to take the Levels; and that at *Pointjoin* seven Leagues above *Chartres*, the Water was higher by 110 Foot than the highest Ground about the Castle of *Versailles*; a plain Instance how greatly that Prince had misapply'd his Money.

VITRUVIUS, *Lib. 8. Chap. 6.* sets down, that the Ancients, in order to the bringing of Water to Towns, Cities, &c. after they had taken the Level, they conducted it three several Ways, by Aqueducts, Pipes of Lead, and Pipes baked in a Potter's Furnace.

THESE Aqueducts which brought the Water to *Rome*, and of which Mention has been already made in the Introduction to this Work, and elsewhere, are describ'd at large by *Fabritti*, a celebrated Architect amongst the *Romans*, with Verses suitable to so great a Work; and

and the Places through which they came are now in Part to be seen, both at *Rome* it self, and in the Prints that give an Account of it; all which is very judiciously collected together in *Montfaucon's* elegant and noble Description of the Antiquities of that great and glorious Metropolis.

“ THE Leaden Pipes were at least nine Foot long, and they made them of bended Sheets or Plates of Lead, of different Thickneses, according to the Proportion of the Largeness of the Pipes; these Pipes had likewise their necessary Declination or Sloping, and if any Valley was in the Way, (by an unnecessary Expence without Doubt,) they made it equal to the Level with a Wall; they likewise had many Vents, to give the Water Air, and to know where to mend the Pipes.” And these, by the Description given of them, are much stronger than the Mould Pipes now made; but of that in its proper Place; the Purport of this Chapter being purely design'd to set down all that is necessary as to the conveying Water by large Aqueducts, whether open and covered, or by smaller Drains, as the next is for all Sorts of Piping, whether in Earth, Wood, Lead, or Iron.

THE Ancients (as is before intimated) chose rather to bring their Water in large Aqueducts, that were so high that a Man might go upright in them, in order, as it may be suppos'd, to mend the Pipes; and had three or four Kinds of Water brought from different Springs, for different Uses, in different Pipes; so that the whole Structure of their Conveniences for Water, was of an immense Height, and brought at an immense Expence, which had certainly the good Effect of keeping the Water clean and pure as it came out of the Spring; whereas Water that is brought in open Carriages, as the *New River* and other Waters are, is subject to be sully'd by Land Floods, and to receive a Kind of a muddy Earthy Taste and Tincture from the several Soils through which it passes, in those so great Distances which it is generally brought.

BUT as these are immense Expences, and such as are scarce consistent with the Pockets of any but the greatest and most opulent Princes and States; and as such enclos'd Aqueducts with Pipes, some of them but of a moderate Size, are not likely to supply Gardens, and large Cities and Towns with the Quantities of Water which are generally there wanted, these open Carriages are absolutely necessary, especially where the Property of the Ground through which you bring them is easily to be come at, that I can't but recommend them beyond all enclosed Aqueducts, both as to Cheapness, and also as to the Quantity of Water they produce: To all which may be added, that

that although the Water may be more fully'd, yet by the kind Affluence of the Sun and open Air, it must be sweeter, and stripp'd of those corroding Qualities that make it so injurious to Man, Beast, Plants, &c. all which thrive better from Water that is taken out of Ponds or Rivers that run gently, than out of cold Springs.

THIS being premis'd, the next Thing to be consider'd is, the *Profile* or Dimensions of such an open-Current or Course of Water; after which we shall consider the enclosed ones of more ancient Make, which do indeed bring Water to any Place clearer and less turbid, and therefore the fitter for Drinking, and the Butler's Use.

THE Depth and Breadth, or, in other Words, the *Profile* of such Carriages, may be according to the Quantity of Water you want, or according to the Supply you have; though I think it cannot well be less than four or five Yards wide at Top, and four Foot deep, that there may be Room for that Sediment with which Water is naturally endued, by its running through Soils of different Kinds; besides, such a Depth, requiring Banks that are sloping, to which you can't allow less than one Foot and a half, or two Foot horizontal for one Foot perpendicular, less Width than that won't do; but if it is design'd to be a navigable Channel for larger Boats, then you can't allow less than thirty or forty, as the Canals that go between Town and Town in *Holland* generally are.

You have been already told how to take the Level from one Place to another, as also how all Levels are to be adjusted, with Allowance for Friction, the Interposition of Air, &c. and what Fall is proper to be allow'd for the Passage of Water from one Place to another; it now remains that some Directions be given how this open Carriage or Drain, call it which you will, be made; in doing which I have a considerable deal of Experience.

You must be sure, in the first Place, to keep up as much as you can in whole Ground; and by the Side of such Hill or Valley as lies near you, for that no Banking can be suppos'd to be of equal Solidity and Security with settled Ground; and you must be sure also to clear away all Sorts Trees, for old Tree Roots will rot and let the Water out, and the Roots of young Trees will be equally dangerous, in as much as they will by the blowing of the Wind loosen the Banks to that Degree as that the Water will run out much to waste there: To this may be added, that rocky Ground, Fox and Rabbet Earths, are Soils very dangerous to make such Works, as I can assure my Reader from dear-bought Experience.

IF good Clay can be procur'd near at hand, it is requisite it should, especially where there is a Necessity of raising Banks entirely new, or for the stopping of Rocks, Fox, or Rabbet Earths, &c. but in other

Ground where you come through that which is whole, there will not be Occasion of that great Care, especially if your Supply be any thing considerable; but one of the chief Cares, will be to close your Joints well between your new and old Ground, and when you build new Banks on old Ground, be sure to go down with your new Clay or Ballast two or three Foot lower than that Ground, and two or three Foot wide, and always mind to mix your old and new Ground together by a Toothing, in such a Manner as the Bricklayers do, that leave it for one Brick to join another.

SURE it is, that whether it be a Ballast, or strong or indifferent Clay, ramming is very necessary, or by laying the Strata's but a Foot thick, or thereabouts, at a time, the Labourers may tread or wheel over it, keeping as exact a Slope towards the Trench as if it was a Garden one; and in all hollow Places it may not be improper to fill them up with waste Earth, not so much to save or hold Water, as to give the proper Base and Support to the Foot of the Bank.

THE inward Sides of the Slope of the Bank, should also be well beat with a large Hedge-Stake before you pare them with a Spade, which it is requir'd you should do. I should not advise to allow less than six or eight Inches, or a Foot in a Mile (if you can have it) Dependance; but surely less than four or five Inches is absolutely necessary, notwithstanding what Sir *Jonas Moore* and some others have noted on this Head. As for the *Profile*, it will be seen *Fig. 1. Tab. seq.*

THE next Method of conducting Water, is that used by the Ancients in their enclos'd Aqueducts: But this is so very expensive that I shall not repeat it here, but rather refer my Reader (if his Curiosity so leads him) to the Works of the celebrated *Fabretti*, which are to be had in some of our Booksellers Shops; and from him Monsieur *Montfaucon*, who has given the Draft of the famous Aqueduct of *Metz*, and other Places; nor are the Works of *Vitruvius*, *Palladio*, and other Architects of *Rome*, to be passed by on this Occasion.

BUT to proceed to those Works, which are made Use of by the Moderns:

THE first is, that of Aqueducts made of Brick or Stone; in neither of which we run to that Expence the Ancients did, not making them so large, nor any Way so expensive. A Drain of a Foot square in the Inside, made with either of the two Materials, Stone or Brick, (but Brick is the dearest,) the other not costing above Ten Pence

Twelve Pence a Yard, though at that Size they will convey vast

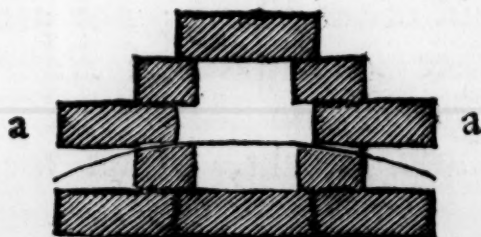
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Quantities

Quantities of Water: But the greatest Inconvenience that attends them is, that if you are to convey the Water a-crofs a Valley, from one Hill to another, these Stone or Brick Drains will not do it, and can be only used where the Water is to run strait, or is to run round upon the Precipice or Side of a Hill upon one Level. You may, indeed, make Wooden Troughs a-crofs Valleys, as above, and support them with a Frame of Wood; but there are many Inconveniences attends them, as the Drought in Summer, which will chop and tear them to Pieces, so that the Water will be in Danger of being lost, or the Trough subject to be cut or broke to Pieces by ill-designing Persons; in all which Cases under-ground Conveyances in Wooden, Leaden, or Earthen Pipes, are the best.

BUT wherever you can carry your Drain strait, (or even round,) and it be an easy gradual Declination, there Brick or Stone Aqueducts or Drains are the cheapest and best, especially where your Spring is large, as six or eight Inches Bore; and then you must lay it in very good Mortar, laid in the Spring, and suffer'd to dry before you turn the Spring into it, bedded also in Clay; and when cover'd over at Top, as it ought to be, with flat Stone, Clay must be ramm'd on the Sides and Top of the same, to prevent any Effluxions of the Water.

BUT the Brick Drain is the next in Course: These can't well be made above six or seven Inches square in the Inside, because a good large Brick, with which the Bottom and Top is made, is not above nine Inches long, and it must lap over an Inch on each Side at Top, and at the Bottom there must be a stretching Brick on each Side, to support the Side-Wall and Back, or rather End. The Construction of this Drain you will see in the Figure following; where the Bricks are placed, Header and Stretcher, in the Manner they are when made into a Drain; the middle Brick mark'd a, may be any bro-



ken Bricks: Every Yard will take up about three Quarters of a Hundred of Bricks, which, at eighteen Pence a Hundred, comes to between thirteen and fourteen Pence, and the Lime and Setting may be worth about two Pence, and the digging and claying a Groat or five Pence more, in all about twenty Pence; and, perhaps, in Countries where
Materials

Materials and Workmanship is cheaper, it may be done for sixteen or eighteen Pence a Yard.

BUT there is another cheaper Way of Brick-Drain yet; and that is when you make a Hollow or Semi-circle of two or three Inches in Bricks, (about four or five Inches thick, and the usual Length:) These Bricks, when plac'd together, and when set in Terras or very strong Mortar, well dry'd before you use it, is the cheapest and most durable Method of any for conveying Water; about eight Bricks will do a Yard, which Bricks are worth three Shillings a Hundred, the eighth Part whereof is about four Pence Half-penny, and the Digging, Laying, and Mortar, may be worth about three Pence or four Pence more. And this is the cheapest Method of all; but must be laid in Clay, as all other Drains and Piping should.

I MIGHT have enlarged a great deal more, in this Chapter, on the Methods which the Ancients made use of in their Conveyances of Water, but that they are very plainly describ'd by the Editors and Commentators on *Vitruvius*, and the other Architects of *Rome*, *Italy*, and *France*; to which I refer my Reader.

C H A P. IX.

Of the several Kinds of Pipes for the Conveyance of Water, whether Lead, Iron, Earth, or Wood.

IT has been already noted, from *Vitruvius*, *Lib. 8. Cap. 6.* "That the Ancients had but two Sorts of Pipes, through which they conveyed their Water; the first was made of Lead, which was of Sheets nine Foot long, and turn'd in at Top;" not unlike, as appears by the Description, some which were made some few Years ago for the Rt. Hon. *George Dodington*, Esq; one of the Lords of His Majesty's Treasury, at his fine Seat of *Gunville* in *Dorsetshire*, the Work of a very ingenious modest Man, and a good Plumber, Mr. *Watts*, of *Brackley* in *Northamptonshire*.

THESE Pipes are join'd together without Solder, by what the Workmen call Flanckets, which are Rings made of Iron, that may be screw'd as tight as you please at the Joint, the Nose of one Pipe going into the Tail of the other; and in order to keep the Water from getting out at the Joint, there are (as I remember) proper Bandages of Leather, that close it up by the Compression of the Flanckets, under which may also be put Taw made of Flax or Hemp, dipp'd either in Oil, Pitch, or Tallow, which will make a close Cement

116 *An Introduction to a General System*

to keep the Water in, and over which the said Flanckets are screw'd. These Kind of Pipes are much to be preferr'd before those made in Moulds, in as much as they are cast without those Flaws and Holes that often happen in Mould-Pipes, and as they are turn'd in at Top, and burnt, (as the Workmen express it,) they are much stronger. Nor is there that Expence in Solder (besides many other Advantages which I shall enumerate in their proper Place) which is in other Pipes. It is true, they are dearer than any other Pipes are, and are chiefly fit for large Pockets; but then they last much longer.

BUT the cheapest Kind of Pipe, which is now used, is that which is made of Earth, and for which Mr. *Edwards*, a Gentleman of *Monmouth*, has a Patent; this Kind of Pipe, *Vitruvius*, *Lib. 8. Cap. 6. prædic.* tells us, were made by the *Romans* of Potter's Clay two Inches thick, and were join'd together with Mortar mix'd with Oil, and when they had a Joint to make, they made use of a red Free-stone which they pierced through to receive the two Ends of the Pipes, and to strengthen and secure them in the Nature of a Bandage.

SOME of these Pipes have been, as I am inform'd, found about *London*, the Laying whereof, by several Circumstances, being supposed to be owing to that great People when they were Inhabitants of this Island; but the Joints were secured by a piece of Sheet-Lead, which was wrapt round the Joint, some whereof I have been told have been taken up in *Hyde-Park*, belonging to the ancient Water-works there.

THOSE which are now made, and for which Mr. *Edwards*, before mentioned, has a Patent, are not above half an Inch thick and three or four Foot long, but they are so exactly made and fitted in the Joint that no Water can possibly come out of them. They are sold from twelve Pence or two Shillings to half a Crown a Yard, and sometimes cheaper, according as they are more or less in Diameter, and are exceeding useful in all Places where they lie free from Coaches or Carts going over them. They are also so strong, that, according to a Letter I have lately seen from the Patentee, he has laid a Reservoir or Head of 300 Foot high of Water; and this, I take it, is at the Right Hon. Mr. Baron *Price's*, in *Herefordshire*. But that is nothing to what follows by-and-by. But to proceed:

BESIDES what the said Patentee makes in the Country, a very ingenious Potter, and Neighbour of mine at *Vaux-hall*, Mr. *Aaron Mutchell* by Name, makes those which are excellently good, not only for the said Patentee, but also for any other Gentleman who may have Occasion for them, he having been one of the first Inventors of them, (as he is also
of

of some of the handfomeft Vases, Flower-Pots, and Urns, which have been as yet any where made, as strong, and equal in Goodness to the Patentee himself, though now he acts by Agreement under him.

THIS I thought proper to say, that Gentlemen may know where to find so extraordinary a Man in this Business.

To conclude: Before I pass over these Sort of Pipes, I can't but insert a Tryal which was made of them the 24th, 25th, and 26th of *July* last, at the *York Buildings*, before the Rev. Dr. *Desaguliers*, when they were fairly try'd with all the Compression of Air and Water that that Engine could lay upon them, and without making the least Fracture, either in the Pipes, or the Cement which join'd the Pipes together; and this Tryal was even before the Plumber of these Works themselves, a general Account of which is to be found in the *Evening Post* of *August 1*, last. All which I mention, because though they are certainly useful in the conducting of any depending Water, yet I could not (from any Thing I had ever observed of this Kind) promise they would be strong enough to bear the forcing of the Engine.

THESE Kind of Pipes are made of a Clay equal to that of which the Tiles of the ancient *Romans* were made, are also used in the Insides of the Walls of Houses, and are affix'd likewise to the Outsides of the same, in the Manner as Lead is, even from the lower to the uppermost Floor; and receive and discharge the Water from the Roof and Gutters of such Houses, as effectually as any Pipes made of Lead or Wood, and are sold for a sixth Part of the Value of Lead, and more than one half of what Wood costs.

THIS new Invention, or, at least, this great Improvement of an ancient one, is of so great a Use to the Publick, that I thought I could not do better than enlarging on it.

But to proceed: There are many other Sorts of Pipes which have been used by the Moderns, which were, as appears by what *Vitruvius* has wrote upon this Subject, entirely unknown to the Ancients, such are those of Wood, as Alder, Elm, Oak, Beech, and Iron, (the last of which are used in *France* more than any where,) but till of late have found little Footing in *England*.

PIPES made of Alder are the cheapest of all, though not the strongest, the Wood, Boring and all, being not worth above Ten Pence or Twelve Pence a Yard; but the Diameter of such Pipe, is generally but small, an Inch and a half, or two Inches, being the utmost Bore it is capable of having, nor is it strong enough to bear

118 *An Introduction to a General System*

bear much Force, but only to conduct a little Spring any small Length, and upon a gentle Current.

IN and about *London*, the Pump and Pipe-Makers use Firr for Pipes, where the Stream is not great, which, as it bores easy, so it is cheaper than that of Elm; but then it is not so strong nor so durable as Elm Pipe is, and is fit only for Works where neither the Rise nor Declivity are either of them great.

Elm Pipe is the next I shall mention, as being much stronger than any of the former, and of known Use for the conveying of Water, and for that it will lie longer under Ground, and in the Wet and Water than any other Sort of Wood Pipe (Oak excepted) will. Now as these are generally made of small Trees and Saplings of different Diameters, the Prices will be different, because thereby they will be either stronger or weaker, and consequently bear a greater or lesser Force, proceeding either from the Force or Lifting of a Wheel, or the Cylindrical Weight of Water which lies upon them where Reservoirs lie high; and it is for Want of Care and due Observation in this Kind of Piping, that Water-Works often miscarry where the Bores are larger than they ought to be, and the Outside or Shell too thin, especially in veiny crooked Trees.

ELM fit for Pipes may be cut down, hewed, or bored, from eight Pence, ten Pence, twelve Pence, to sixteen, eighteen, or twenty Pence a Yard running, Timber and all, five Pence or six Pence a Yard Boring being a sufficient Allowance. But for the quicker Expedition of this Work, I have given the Draught of an Engine for boring by Water, which will be exhibited in its proper Place.

I have examined the Prices of Elm Pipes about *London*, and find, as hinted before, that they are according to the Thickness or Strength of the Pipe, which ought to be either more or less, according to the Weight they are to sustain.

THE following Prices are taken on a Medium, being Sizes of Pipes which are generally used.

	s.	d.	
7 Inch Pipe	5	0	} is worth about } per Yard.
6 Inch Pipe	4	6	
5 Inch Pipe	3	0	
4 Inch Pipe	2	6	
3 Inch Pipe	2	0	
2 Inch Pipe	1	3	

THESE may be all had at Mr. *Hewit's*, and other Pump-Makers, in *Lambeth*, and other Places on the *Bank-Side*.

THOSE

THOSE who have the most to say against Elm Pipe, urge, that there is a great Waste of Water at every Stroke of the Engine, which forces the Water with great Violence through the Pores of the Tree: But this I take to be an Ease to the Work, and not at all different from Nature, but is rather a Relief than a Burthen to the Machine and the Passage of the Water in the Pipes, which is very often in closer Bodies so Wind-bound, that it won't pass. There is another Convenience which attends these and all other Wooden Pipes; and that is, that you may at any Time, when Pipes are Wind-bound, which they often are, when they lie long unus'd in the Ground, that then you may bore a Hole at the very Place where you perceive the Stoppage to be; which is what you can't so well do in those other Pipes which are made of Metal.

ANOTHER Sort of Elm Pipe, which is, I conceive, as strong, if not stronger, and more durable than the former, is made square, and of Elm Plank, the Contrivance of a late worthy ingenious Gentleman and Friend of mine, *John-Thyrle Ernby, Esq;* of *Whetham*, near *Sandy-Lane, Wilts*, on the Road to the *Bath*.

THE Boards of which those Pipes are made are generally about ten Inches square, and an Inch and three Quarters thick, but you may have them of a Foot or fourteen Inches square, but then they must be two Inches, or two Inches and a Quarter, or two Inches and a half thick.

THE Sides are to be well groov'd into the Bottom and Top, and the Joints are to be well pitch'd, or stuff'd with Tow or Hemp dipp'd into Pitch and Tar, to keep the Water from oozing out; after which they are to be banded or collar'd at about five or six Foot asunder, with Collars or Bands made of Elm Slabbs, or Planks, cut out of the Sides of the Elm, and this will be stronger, more natural, and more durable than any other Bandages are, and will save Iron Hoops, which are expensive.

A BOARD or Boards of ten Inches square, will, when groov'd in at Bottom and Top, make a square Pipe about four Inches and a half, or five Inches square, which last is near equal to a circular Pipe, whose Diameter is six Inches.

To proceed in the Work, be provided with Taw, or coarse Hemp, as also Pitch and Tar, and dipping the Taw or Hemp into the Tar, put it into the Groove or Joint, and then let the Workmen knock the Boards together in the Groove, with all the Might and Strength they have, it being in the Closeness of this Joint that the Security of the Water in the Pipes consists.

120 *An Introduction to a General System*

THIS done, put on the Collar or Bandage, one at each Joint, the Boards being about nine or ten Foot long, and another Collar in the Middle, putting the small End of one (so made, as you do in Elm Pipe which is bored) into the great End of the other.

HENCE follows an Estimate of the Expence of this Kind of Pipe, or rather Trough, which I recommend more than that which is bored; for that in the first Place it is stronger, and may be made five, six, or seven Inches square, which will carry more Water than bored Elm Pipe of the same Diameter will.

IN the next Place, there is less Depopulation and Waste in cutting, (a few large Elms at full Growth, being sufficient for this Purpose;) whereas when you cut them down small there is a great Waste made. And, in the last Place, it being all Heart, it will not be so subject to break or burst as Elm bored will.

Here follows the Expence of 330 Yards running, which I my self caused to be made in the same County of Wilts.

	s.	d.	q.
For 20 Tun of Timber at 30 Shillings per Tun,	30	0	0
Felling and Hewing of ditto, at 8 Shillings per Tun,	8	0	0
For 330 Yards of Workmanship, at 4 Pence per Yard,	5	11	0
For Nails, Tar, Taw, or Hemp, Banding, Collaring, and Laying included, at 3 Pence per Yard,	4	2	6
	47 : 13 : 6		

By which it appears, that the whole 330 Yards comes to forty seven Pound thirteen Shillings and six Pence; which being reduc'd into Shillings, Pence, and Farthings, and divided by the said 330 Yards, it comes to about two Shillings and ten Pence a Yard; whereas Lead Pipe of such a Dimension would cost at least twenty Shillings a Yard, and bored Elm five or six Shillings. But I have since found that four Pence a Yard is too little for the Workmanship by two Pence, and so it will cost just three Shillings a Yard, which I take to be a very reasonable Price.

ONE of the last Kinds of Piping which is generally made of Wood, is Beech, which being of a more firm and solid Contexture, and less porous than Elm or Oak, will lie under Ground longer than either of them, as may be seen in all Mill-Work, in which this Wood is much used; but like many other Woods has an Inconvenience attending it, that it bores pretty hard, is brittle, and not so tough grain'd
as

of Hydrostaticks and Hydraulicks. 121

as Elm or Oak is ; besides, the Boughs don't run so strait, generally speaking, as Elm does, and therefore the Shell of it ought to be very thick, not less than five or six Inches to keep it from bursting ; and in such a Case the Bulk or Dimensions of it ought to be twelve or fourteen Inches diameter, one with another, when you may venture at a Pipe of two or three Inches Bore ; and though its something difficult to bore, yet the Water will be less subject to ooze out, than at any of the others, Oak itself not excepted.

THIS Sort of Piping, the Property of the Wood, digging the Trench, Boring, Laying, Claying, and Banding, will be worth three Shillings, or three Shillings and six Pence *per* Yard, for a Bore of four Inches, and so on proportionably less, as the Wood or the Bore is less : But then it must be observed, that it is the nearest the Goodness of Lead of any that is a four Inch Pipe, which Lead will cost fifteen or sixteen Shillings ; as will by-and-by be set more plainly appear.

THE very last Kind of Wooden Pipe is Oak, which indeed is very strong, and lasts a great while, there being some Trees of that Kind which (under my Supervisal) were dug out of the Foundations of *Blenheim*-Bridge, that were, though as black as Ebony, yet as sound as Brazil itself, and might in all Probability have no other Date than that of the Deluge itself. But as the Limbs are generally crooked, and that all the young Bodies together, with the whole Timber itself, is too good for those Purposes, I shall omit saying any Thing more on this Head.

THE next Piping to be mentioned, are those made of Potters Earth, of which I have said something already. There are two Kinds of these at least : They are of two Thicknesses in the Shell ; the first being the most in Use in the Country, is not above the Thickness of two Crown-Pieces at most ; but this is so thin, that it is fit only to convey Water a little Way were the Fall is not great. These may be bought in many Places of the *West* for six Pence a Yard.

THE other is the new-invented ones already nam'd, which nevertheless are not above half an Inch thick in the Shell, more being, according to the Opinion of the Potters which make them, entirely useless, at least they can't burn them so well.

THESE are excellent Pipes when glaz'd in the Inside, as they ought to be, to keep Water sweet ; and how they will do in Force-Work has been already set down.

THERE is a Complaint made against them, how true I know not, That there is a Weed apt to grow at the Place where they are jointed together, the Fibres of which are apt to choak the Pipe up :

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But this, if true, may certainly be prevented, if you put on a thin Bandage of Lead round the Joint, or if you put a Collar of Stone or Wood, to strengthen them, you may prevent that Mischief.

THE Manner of mending them when broke, has been another Objection which has been brought against them; for if the Joint be made of such a Cement as that the Pipe will rather break any where than there, it does not seem easy to tell how they are to be amended. Now in answer to this, the Joints that I have seen at my ingenious Neighbour's at *Vaux-hall*, shoot so close together, that there is little Occasion of any Cement; but when they do, Taw dipp'd in Pitch and Tar, or any other Cement of that Kind, will effectually stop it, at least, the Loss of Water will not be great where the Supply is any thing large, and then they may be uncollar'd and mended at Pleasure. But of this more in the Notes on this Book.

THERE is one Thing to be observ'd, which is certainly true, and that is, that they won't do in High-ways and Streets, where Carriages and Coaches are to cross them, but on all other Accounts they are excellent Pipes, and a cheap Conveyance.

OF all the Sorts of Piping for the Conveyance of Water, that of Lead is preferable, (especially those which are made of Sheet-Lead, and burnt at Top,) were it not for the Expence, whether we consider them as being more pliable to lay up and down Hill, as they are easier and more firmly jointed to one another, or as they are as durable as any other, and if well cast of a much closer Contexture.

IN Pipes of Conduct, and where Water is conveyed a great Way, the Diameter ought to be six or seven Inches, but four or five Inches at least, because in Pipes of that Size there is less Friction and Wind-boundedness than in these which are smaller, and consequently the Water will flow the better and rise up to the Height of its first Head more regularly, and in greater Quantities.

It must indeed be own'd, that a Pipe of Conduct of so large a Dimension as I have just now been naming, is such an Expence, that few Noblemen or Gentlemen are willing to be at the Expence of, especially in very great Lengths, where the Expence is almost immense; Pipes of that Kind, without a Shell of Thickness proportionable to it, being worth from twenty five to forty Shillings a Yard, according to the Height of the Reservoir, or the Force they are obliged to sustain.

A PIPE of Conduct therefore of the cheapest Kind, must be at least four Inches and a half or five Inches Diameter, and this will cost at least sixteen or eighteen Shillings per Yard. This has been the Occasion that in many Places they have reduc'd their Pipes
of

of Conduct to three Inches Diameter, which is indeed too little, though thereby the Expence is reduc'd to about ten or twelve Shillings per Yard, according as the Price of Lead is.

It will be to little Purpose, for me to urge that Pipes are dearer or cheaper in Proportion to their Dimensions and Thickneses, and consequently to the Price of Lead, and the Allowance in Weight which is made to every Foot or Yard; but the following is a Calculation made for a Person of Quality, for whom I have had the Honour to be employ'd; and where Lead, Casting and all, is reckon'd at twenty two Shillings per Hundred.

To a Pipe of three Inches Bore, there is allowed forty five Pounds a Yard; and this is worth about nine or ten Shillings a Yard, when Lead is worth from twenty two to twenty five Shillings per Hundred Weight, allowing for Waste.

To a Pipe of two Inches three Quarters forty Pounds is allowed, which is worth between eight and nine Shillings a Yard.

To a Pipe of two Inches and a half, thirty six Pounds is allowed, and then it is worth about seven or eight Shillings a Yard; but it would not be amiss to add five Pounds more to every Yard, though it aggravate the Expence something.

To a Pipe of two Inches Diameter thirty Pound of Lead is allowed, which is worth about six Shillings per Yard.

BUT of all the Pipes made of Lead, of what Size soever, those which are join'd together by Flanchets (as has been already intimated in the Beginning of this Chapter) are the best, which may easily be taken up, and scour'd or cleans'd, whenever the Owner pleases: Because, as *Marriotte* truly observes, there is, even in the finest Water, a Sediment, which will in time petrify, incrustate, and grow hard, and will stop up the Pipe, which can never be clean'd again where Pipes are solder'd together at the Joints with Solder, as Pipes generally are. And this is one (amongst some other of the Misfortunes,) which attend all Water-Works, and is the Occasion of their being spoiled.

I HAVE already mentioned something concerning the Lead which is proper to be allowed to Pipes in general, according to the Proportion or Diameter of their Holes: But when Reservatories are very high, or Water is rais'd by an Engine to great Heights, or carried to great Distances, there Pipes of Conduct are in Danger of being often broke, if the Shell is not thick enough, especially up and down Hills, and through deep Valleys; and it would give a Man a good Deal of Uneasiness, after he had been at great Expence, if his Pipes should happen to burst through the Defect of the Solder,

124 *An Introduction to a General System*

or the Weakness of the Pipes. At the same time Care should be also taken, on the other hand, not to make them thicker than is absolutely necessary, since a small Addition in long Lengths would greatly enhance the Price.

BUT it is proper we should understand from Experience, (as well as from what *Marriotte*, and others, have delivered on this Head,) that the Thickness of the Metal, or Shell of the Pipes, be increas'd or diminish'd in Proportion to their Diameters, the Heights of the Reservoirs from which the Water falls, or the Height to which it is to be rais'd by Engines, and last of all, the Lengths or Distance which Water is to be carried; all which adds to its Cylindrical Weight, and consequently the greater Thickness of Metal in the Pipes.

FOR Example, according to *Marriotte*, when a Reservoir is sixty Foot high, and the Pipe three Inches Diameter, the Metal must be half a Line in Thickness, which is the twenty fourth Part of an Inch; but as this ingenious Author undoubtedly means Copper, which is harder, stronger, and of a closer Contexture than Lead, I should not advise less in such a Case than three or four whole Lines, which is one third or one fourth Part of an Inch; and to a Reservoir 100 or 120 Foot high a whole Inch, because of its great Height.

IF the Pipes are both wider and higher, then the two Proportions must be also observed: Thus if a Pipe comes from a Height of sixty Foot, and the Diameter be six or eight Inches, you must take the half Line in Copper, or rather three Lines, or the Quarter of an Inch in Lead, because of its Height of sixty Foot; and for the Thickness, you must work by the *Rule of Three*, saying, *If nine, the Square of three Inches, requires three Lines thick of Metal, what will thirty six, the Square of six Inches, require?*

E X A M P L E.

As 9 is to 3, so is 36 to a 4th Number requir'd.

$$\begin{array}{r} 3 \\ \hline 9) 108 \text{ (12 Lines is the } \textit{Ans}^{\text{w}}. \\ 18 \\ \hline \end{array}$$

So that a Pipe of six Inches Diameter, when it comes from a Reservoir sixty Foot high, should be twelve Lines, or one Inch thick; near or according to which the following Table is calculated.

BUT

BUT before we come to it, there is another Thing to be determined, and that is the Diameter of the Adjutages; a Piece of Knowledge that undoubtedly belongs to this Head.

THE ingenious Author of the *Theory and Practice of Gardening*, says, that it may be taken for a certain Rule, that the Bore of the Adjutage ought to be four Times less than the Diameter or Bore of the Pipe of Condu&t, that is, they should be in a Quadruple Proportion thereto, so that the Column of Water may be proportionable, and the Quickness of the Motion in the Pipes may be equal: Besides, as is elsewhere observed, there is too great a Friction and Wear in small Pipes, when the Quill is too big, and in the Bore of small Quills when Pipes are too large: All this, I say, likewise depends on Calculations of this Kind, which will necessarily be included in a Table, where the Diameter of Pipes of Condu&t, Thickness of Metal, &c. are contain'd.

AGREEABLE to what I have before observed, the Calculations *Mariotte* has made on this Head, are undoubtedly for Copper, Lead being not so much us'd in *France* as it is with us in *England*, especially in Time of War, when they have none but what they get from our good Friends and Allies the *Dutch*. On this Account I thought it was proper for me to pitch upon a Pattern of a Lead one, which should determine all that is requir'd on this Subject; which I have done from a Pattern in the *West*, (the Work of a very good Plumber at *Hungerford*,) which by all good Judges is accounted a most excellent one.

THE Pipe is four Inches Diameter, which is generally supposed to be a good Pipe of Condu&t, (though in some Cases more is requir'd,) and about equal to the Expence that most Noblemen and Gentlemen are willing to be at.

THE Thickness of the Metal, which is of Lead, is six Lines, or half an Inch: To regulate then the Thickness of other Metal to it, say, as before, *If sixteen, the Square of four Inches, requires six Lines; how much does thirty six, the Square of six, require?*

E X A M P L E.

$$16 : 6 : 36$$

6

$$16) 216 \text{ (} 13 \frac{1}{2} \text{ is the Answer.}$$

56

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By

126 *An Introduction to a General System*

By rejecting the Fraction it appears, that the Thickness of the Metal requires to be thirteen Lines, or one Inch one twelfth: And from this it is that I have form'd the Column concerning the Thickness of Metal in Pipes, which is (I take it, without any considerable Variation) agreeable to Truth, which expresses also the Height that the Water coming from the Reservoir will rise. Here follows the Table.

Height of the Reservoir.		Diameter of the Pipes.		Thickness of the Metal.		Diameters of the Adjutages.		Height the Water will rise to.	
Feet.	Inch.	Inch.	Lines.	Lines.		Lines. Parts.		Feet:	Inch.
100	0	7	00	15 $\frac{1}{2}$	16	12 or 15		80	00
86	4	6	00	14	00	12	14	70	00
72	0	5 $\frac{1}{2}$	00	12	13	10	12	60	00
58	4	5	00	9	9	8	10	50	00
45	4	4 $\frac{1}{4}$	00	7 $\frac{1}{2}$	8	7	08	40	00
33	0	3	00	6 $\frac{1}{2}$	7	7	00	30	00
21	4	2 $\frac{1}{2}$	00	5 $\frac{1}{2}$	6	6 $\frac{1}{2}$	00	20	00
15	9	2 $\frac{1}{4}$	00	4	5	6	00	15	00
10	4	0	25	3 $\frac{1}{2}$	4	5	00	10	00
5	1	0	22	3	3 $\frac{1}{2}$	4	00	5	00

THUS far of the Diameters of Pipes of Conduct, Thickness of the Metal, Diameters of the Adjutages, &c. as are, or ought to be proportionate one to another. But if any Gentleman has a Mind to have his Pipes of Conduct larger than any above mentioned, he may; the Use of this Table being chiefly calculated for all proportionate Heights.

WHAT I have to add to this Chapter, is, to give some Account of Iron Pipes, which are now growing into great Use, and are, in respect to their Cheapness, the best Pipes, Clay excepted, which are now made, especially if the Metal is well proportioned and melted. But it must be observed, that the Casting of them very small is no great Advantage, the best Sizes being from seven or eight to five, four, or three Inches Diameter; the first of which will cost about twenty Shillings a Yard, which is a great deal cheaper than Lead; and the last, from ten or twelve to fifteen or sixteen Shillings, or perhaps cheaper, as they are more or less in Bulk and Diameter.

THESE Kind of Pipes are the most durable of any yet mention'd: They are cast about two Yards, and sometimes three Yards long, and that but seldom: They are join'd together by Flanchets, as may be seen

seen in the Water-works on *London-Bridge*, or as I have before describ'd those which are made at Mr. *Dodington's* of Lead, as I have been well inform'd, by a very ingenious Gentleman, if well made, will last, as it were, for ever.

THIS, and all Foundery-Works of this Kind, are well perform'd, and Gentlemen may expect to be dealt well with, by Mr. *Bowen*, at his Foundery near *Marigold-Stairs, Southwark*, where Garden-Rowers, Pallisadoes, and other cast Iron-Works, are to be had. And so much as to Pipes.

C H A P. X:

Of Reservoirs, Basins, &c. the Method of making them, their Construction, proper Extent, Depths, and other Dimensions.

WE are told by *Vitruvius, Lib. 8. Cap. 6.* " That the Method the Ancients us'd in making their Walls and Cisterns to receive Rain and other Water, was under Ground, and of a very large Extent; and Walls were built on the Sides and at the Bottom with Mortar made of strong Lime, Sand, and Pebbles, well beaten together; " Claying not being, it may be supposed, so well known, or to be had in such Quantities as now it is.

" Of these, says our oft-quoted ancient Author, they made several, one after another, through which the Water was to pass, to the End, that the Sediment might remain, (if any there was) in the first and second, and so that when the Water was arrived at the last it might be clear. They likewise put Salt into their Cistern-Water to make it more subtle.

IN this Manner also were the remarkable Cisterns of *Roselayn* made, viz. with no other Materials, as has already been intimated, than Gravel and small Pebbles consolidated together by a strong tenacious Cement, perhaps, such as *Terrass-Mortar*, or the like.

AND certain it is, that too great Care can't be taken in making those useful Reservatories, as daily Experience shews, especially if it be upon a dry Gravel or Sandy-Bank, and is to lie above Ground, as is evident from that very handsome one behind his Grace the Duke of *Chandois's* intended Building near *Cavendish-Square*; where the
Expence

Expence of making and fitting it (with how great Success, I can't tell) has doubtless been very great.

WITH us in the *West* (from whence this is wrote,) every Ploughman and Shepherd is able to make good Reservoirs or Ponds for holding of Water; Clay also, that is good, abounding much with us. The Method of doing which I shall lay down by-and-by, when I have said something as to the *Profile* and Disposition of these Reservoirs, and the Manner how they are built in several Places.

As to the Form of which these Reservoirs or Basins are made, it is of no great Consequence, though a Square or an Oblong are as good Figures as any: And as to the Extent, it is undoubtedly according to the Quantity of Water which is requir'd, 100, 150, or 200 Foot square, being sufficient in most Cases; though for large Cities, Towns, &c. 300, 400, or 500, is not more than enough: But the deeper they are, the better; contrary to the Practice of some that I have lately observ'd, which have not been above three or four Foot deep, when I judge they ought to be from seven or eight to ten or twelve Foot deep, that the Water may settle the better; and the Bottom should be fill'd two or three Foot high, with large Gravel-Pebbles; by which Means the Sediment will have Room to lodge and settle therein, and this Bottom should be well Clayed, and lie lower by three or four Foot than the Bottom of the Aqueduct that brings the Water in, for the Purposes before mentioned.

If the Reservoir be but small, as fifteen or twenty Foot over, then I would advise the Section of it to be made Conoidal; because by this Shape it will happen, that the Pressure of the Water on the Pipe of Conduct will be regular and uniform, from the Beginning to the End of the going out of the Water.

By this Conoidal Form it is, that *Archimedes*, in some excellent Propositions of his, in his two Books *de Insidentibus Humido*, demonstrates the Gravitation or Pressure of Fluids one upon another, which was also followed by *Gallileo*, *Torricelli*, and others.

To this Purpose also, *Marriotte*, in his Rules for the Measuring of spouting Waters, through Adjutages of different Bores, *Discourse* 111. *Pag.* 185. of the *English* Edition of his *Hydrostaticks*, sets down a very curious Problem, which he says *Torricelli* has not undertaken to resolve, though he propos'd it. This Problem is, to find a Vessel of such a Figure, that being pierc'd at the Bottom with a small Hole (when the Vessel is small, but larger as a Vessel or Reservoir is larger,) that the Water should go out, its upper Surface descending from equal Heights in equal Times.

LET it be a Conoidal Figure, *Fig. 1. Tab. seq.* where BL is to BN as the Square squared of NO , and BN to BH as the Square squared of NO to the Square squared of HK , and so on: The Water will descend from ADC in an uniform Manner, till it comes to the Hole at B . For let BP be the mean Proportional betwixt BD and BH , since the Square squared of KH and of DC are to each other as the Heights BH , BD , the Squares of HK , DC , will be in a subduplicate *Ratio* of BH to BD ; or as the Heights BP , BD . But the Velocity of the Water that goes out at B , by Reason of the Pressure of the Height BD , is to the Velocity of that which goes out by Reason of the Pressure of the Height BH in a subduplicate *Ratio* of BD to BH , that is to say, as BP to BD : Therefore the Velocity of the Water descending from H , is to the Velocity of the Water descending from D , as the Square of HK to the Square of DC : But the circular Surface of the Water at H is to the circular Surface of the Water at D , as the Square of HK to the Square of DC ; therefore they will descend and run out one as fast the other: And if the Surface ADC runs out in a second, the Surface GHK will run out in a second likewise, since the Quantities are as the Velocities.

THE same Thing will happen to the other Surfaces at E and F , &c. but the Hole must in all minute Cases be very small, that no considerable Acceleration may be made, and that the Water may not go throughout the Hole sensibly, but in a Proportion to the Weight. A Vessel of this Model, says the ingenious *Marriotte*, may serve for a Clepsydra or Water-Clock; and, I add, for any Reservoir for supplying and playing Fountains or any other Water-Works in Gardens, or for the regular Distribution of Water for the Use of any City or Town; and is still the more useful and proper to be made, when the Spring rises near the Place where the Water is to be us'd, as does that of *Longleat* in *Wiltshire*, the Seat of the Right Honourable the Lord Viscount *Weymouth*, and other Places.

THE Section or *Profile* of a Reservoir being thus set down, pertaining as it does to those only which are narrow and deep, as all Reservoirs must be, which are made on the Side of a Hills and near a Spring, it will be requisite that I inform my Reader, that the Structure of such Reservoir or Cistern be of Stone or Brick, since there is no working of Clay to stand in so perpendicular a Manner as the Figure describes. But when we come to make Reservoirs of that great Extent which they often are, this *Profile* or Section can be of no great Use, nor can the Figure of it be followed.

It is more to the Purpose then, that we lay down a short Account of those Rules which are necessary to be observ'd in the *Profile* and Disposition of Reservoirs that are made of Clay, and the Methods of Digging, Picking, Cleansing, Beating, or Ramming of that useful Material.

THE Slopes then on each Side, and at the Ends of any Reservoir, if the same be made of Clay, which is by much the cheapest of any Material wherewith Reservoirs or Ponds are usually made, should be at least three Foot horizontal to one Foot perpendicular, that they may stand well, and not be so subject to Mouldering: So that if a Reservoir be seven or eight Foot deep, which I would by all means advise in Works of this Kind, the Basis of the Slope ought to be twenty eight, thirty, or thirty two Foot; the *Profile* or Section of which see *Fig. 2. Tab. seq.* and the Banks should be freed of all Trees and other Incumbrances, which are apt to tear the Banks by the Rocking and Blowing of the Winds. As to what relates to the Time of making Reservoirs, the Digging, Picking, Cleansing, and Ramming of the Clay, take the following Rules:

THE best and most proper Season for digging of Clay and making Reservoirs, and other Water-Works of this Kind, is generally about *Michaelmas*, after the first Rains have fallen; for then the Clay works well, and the Season is coming on to be cool, and in such a Manner that you may expect the Rains will fill your Work, in case your Supply should be precarious.

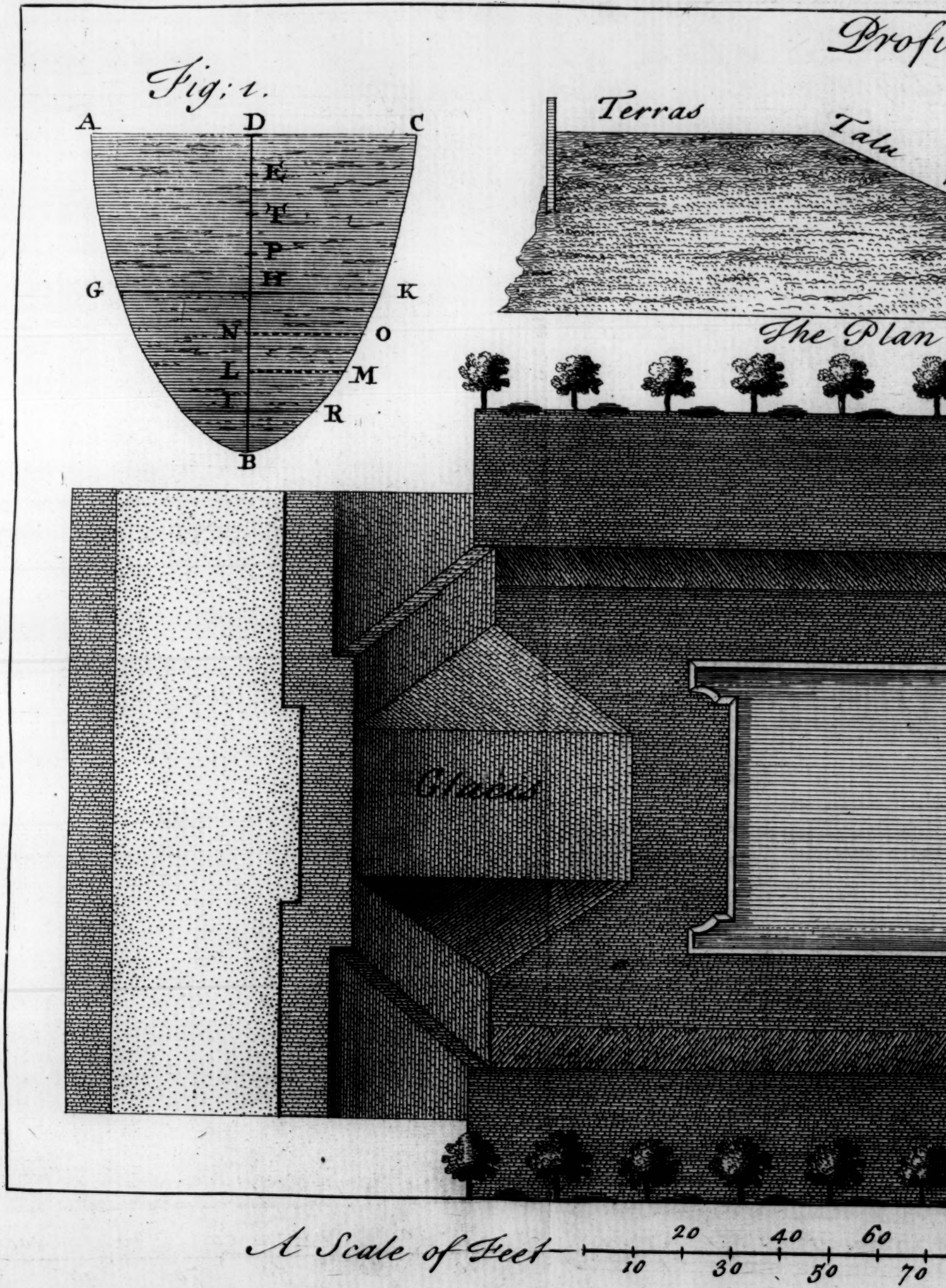
THE Shape of the Reservoir or Pond being first made, you are to dig your Clay, and use it immediately; otherwise you will be oblig'd to water it, which will spoil it: And you should be very careful to pick it clean of all large Stones, Sand-Holes, and Veins, and to throw out all such Parts of it as any way degenerates from the general Mass or Vein of Clay you dig.

YOUR strong reddish or yellow Clays are accounted best; but there are white and blue Clays which are as tenacious as any of the former, though they may not be so ductile, nor work so well. The West-Country Pond-men, as I have very lately observed, chuse that Sort of Clay that has some small Parts of Pebbles or Gravel in it; because, say they, it rams the better. Clays run often in Veins; but if you dig it in Pits where it lies deep, the deeper you generally go, the better and stronger the Clay is.

ASOON as ever you have found that which is good, and it is dug, carry it to the Place where there is Occasion for it, and use it immediately, before the Sun and Air has harden'd it so that it won't work: But if you have not an immediate Occasion for it, cover it

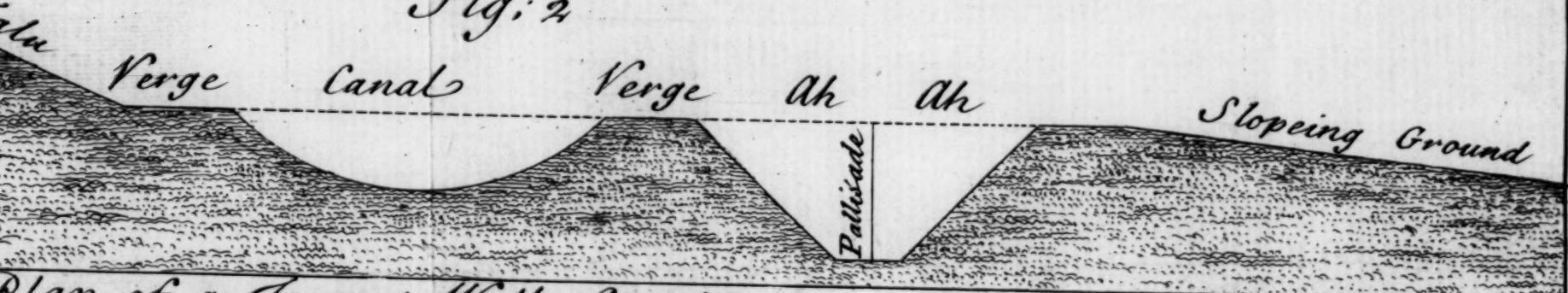
over

Plate 3

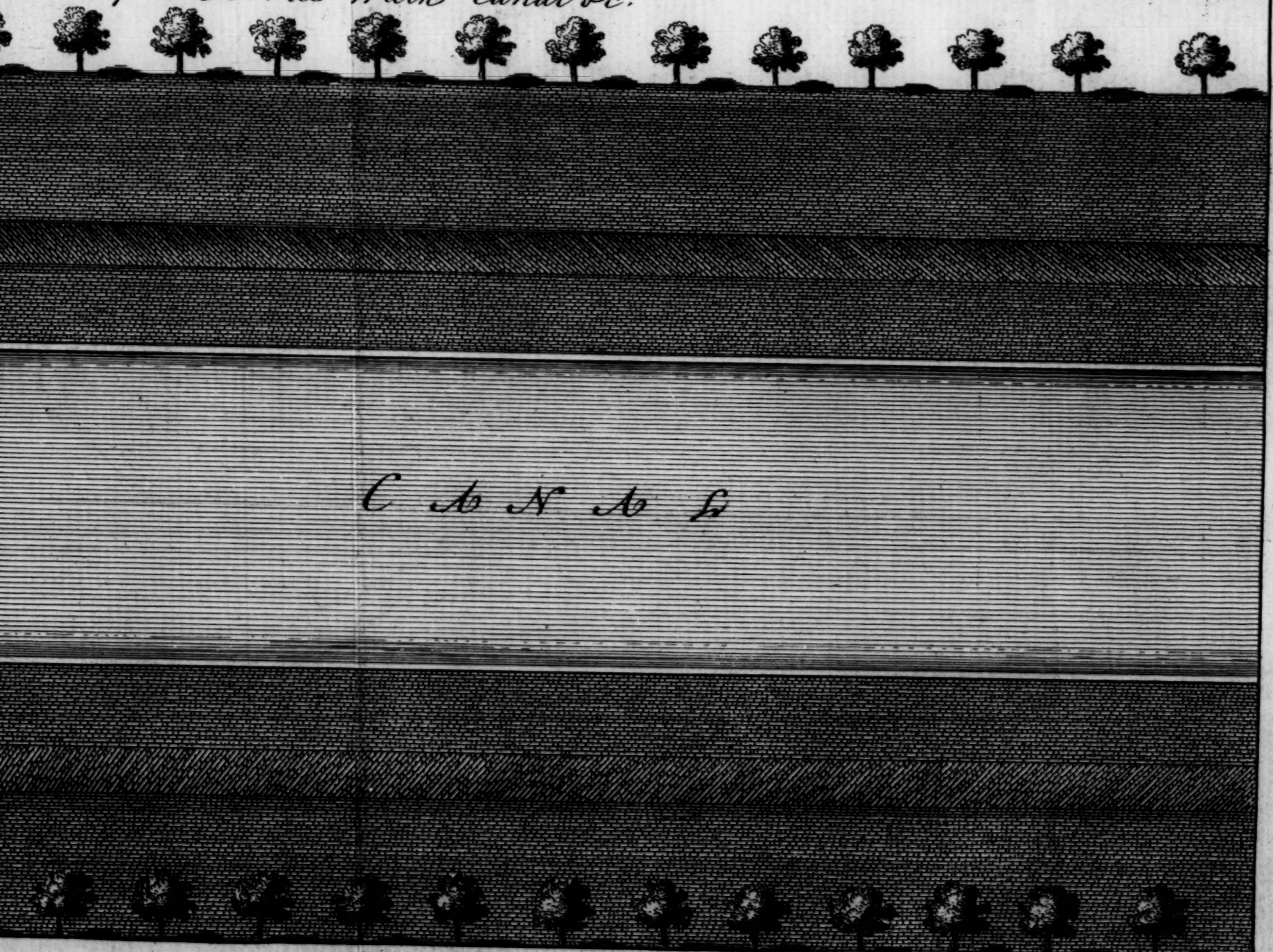


Profile lines for a Reservoir Canal &c.

Fig: 2



Plan of a Terras Walks Canal &c.



Toms sculpt

over with long moist Horse-Dung, or wet Hay, or Thatch; and when you bring it to the Place where it is to be used, begin in the very Middle or Center of the Bottom of the Pond, where you are to lay it thicker than ordinary; and so work every Way from it, treading and beating it well as you go with Instruments, which I shall give a more large Account of by-and-by.

It has been much disputed amongst Workmen, and there is a Kind of Uncertainty in all the Books I have read on this Subject, how thick Clay should be laid, without telling us in what Manner it ought to be wrought, some allowing a Foot, some a Foot and a half, and others more, for the Thickness thereof: Nor do they mention what is practis'd amongst Workmen, namely, the laying it not all at once, but in two distinct Layers of about six or eight Inches thick at most.

WHEN you have begun in the very Center or Middle of the Reservoir, as above mention'd, and laid it there about six or eight Inches thick, you may throw the Horseheads or large Spits of Clay together, just as they are dug out of the Pit, only picking out the large Stones, or any Veins of Sand you can find therein; having always at hand a large heavy Beater or Beetle, such a one as you cleave Wood withal, and with that work it well together; and having done a Yard or two at a Time in that Manner, you are to have ready at hand another flat Beater, such as those you beat Grass with; or, which is better, let it be made in the Manner which a hard Brush is made, wherewith Maid-Servants rub their Rooms, but a stronger Handle, and in the Head thereof fix four or five strong Iron Teeth, which will, as it were, cut or scratch a-cross the Joints, to prevent any open Chasm or Crack that would otherwise be there: Which done, take such a Rammer as Paviers use, (though it need not be quite so heavy,) and smooth it over. This done, you had best lay a little long Dung, Hay, or Thatch, as before, to keep the Clay from cracking, till you come on with your second Coat.

THE first Coat being laid quite over in the Manner thus directed, you are to strow some slack'd Lime all over it; for this won't only corroborate, and make the Clay grow hard and dry, and, as it were, almost impenetrable, but it will prevent the Worms from working in the Clay, as our Pond-Makers in the *West* tell me.

THIS done, you are to begin again in the Bottom the same Thickness as you did at first, and work every Way from the Center, proceeding in the same Manner as you did before, taking Care, above all, to break, join, or close the Clay well, as by the Instrument with Teeth you may very well do; and you will have this Certainty in doing the Work

over again, that if there should be the least Crack or Perforation in one Layer, the other coming over it again will fill it up, and supply the Place that may be occasion'd by such a Default.

UPON the upper Coat of all you are to put a little more Lime and Chalk mix'd together, and ram it on three or four Inches thick; by which Means it will incorporate into the Clay, and make, as it were, one solid Body, which you may pitch with Flint Stones, if there be Occasion, that is, if Cattle have Egress and Regress thereto for Drinking. However, all Reservoirs, if they are not Wharfed with Wood, Brick, or Stone, (which I would not advise as being very expensive) ought to be pitch'd a Foot or two below the high Water-Mark, to prevent the Washing away of the Clay on the Sides of the Reservoir; as also the Working of Moles, Mice, and other Vermin, that spoil the Banks.

THERE are, who are so exact as to lay a third Laying or Coat of Clay over the other two, and of the same Thickness, *viz.* six or eight Inches: And this is, indeed, a very commendable Way, and very necessary in Grounds that are of a dry, gravelly, husky Nature. One of this Kind I remember to have been concern'd at my first setting out in Pond-Work in *Essex*, which ran out so fast till the Pores of the Earth were fated, that an Engine which was three Days and Nights employ'd, could scarce keep it full, so that certainly three Times Claying is much more secure, and the Expence not much larger. The Digging and Claying of a Reservoir or Canal twice is worth about twelve Pence a Yard superficial; and if they were to be Clayed a third Time, it would not be above three Pence a Yard more: But then all the Clay must be brought to the Place, the Carriage of it being so uncertain that no Undertaker can well tell how to do it. But I know some of our Head West-Country Pond-Men have had eighteen Pence a Yard for two Layers of Clay only.

It has been already advis'd that the Bottom should be fill'd with Gravel, Pebbles, or the like; which lying upon the Chalk, will contract the Sediment and Slime, which naturally comes along with Water, and will make it look more pure and clear.

AND I have farther very lately observed, that the Pond-Men in the *West* do not pitch their Fish-Ponds so much as they used to do heretofore, but lay six or eight Inches of Chalk upon the Clay, which is better for all Sorts of Fish than pitching: The Fish-Ponds on *Black-Heath* are, as I am told, bottom'd with Heath.

I HAVE also already mention'd the Method the Ancients us'd in having Cisterns one within, and often below one another, that Water which was foul, might be strain'd through, and leave its Sediment

in its Passage through them; but what I would recommend in this case, and what is much cheaper, is Hills of the finest Sand you can conveniently procure, such as in its own Nature it is not subject to be dirty. When the Water comes in, then let it be at one End, having three or four of these Sand-Banks lying a-crofs our Reservoir, give the Water Time to filtre through, and let the Pipe which is to supply your Fountains lay at the farther End, so may you expect to have your Water clear, and there Sand-Banks should lie and be above the Surface of the Waer, when it is highest of all.

I HAVE already, I think, mentiond that about *Michaelmas* is the most proper Time for such Works, in as much as the Weather is then the coolest, and that there is, in Case of any dubious Want of Water, sufficient Time for the filling the Pond; but the Winter or Spring, or indeed any other Part of the Year will do as well, provided you dig your Clay, and use it immediately, and that you have a River, a strong Spring, or some very good Engine to fill it: But you must beware of Frosts, and of the drying cutting Winds of *March*, which do more Hurt to new Ponds, than any other Variation or Change of Weather does. What relates to the making Reservoirs for Ponds with Brick or Stone, I shall set down elsewhere.





NOTES upon BOOK I.

CHAP. I. PAGE 6. LINE 15.



AND that the Architect has allowed five Foot in a Mile for the Descent or Current of the Water. Upon a second Revival of this Passage, and the 2d Edition of Mr. Addison's *Travels*, I find it is five Foot and an half in a Mile Fall, that the Romans allowed for the Conveyance of their Water in their Aqueducts and enclosed Pipes; which is nearly agreeable to what has been allowed in the Chapters going before; especially in all great Lengths, where the Friction is considerable. And this Passage of Mr. Addison's confirms an Observation made in this Treatise, That it was by this Means, viz. by going back a good Way, that the Romans could take up their Water from what Height they pleased, without the Expence of such an Engine as Marli.

Chap. I. p. 10. l. 41. It must be confessed that we are not yet arrived to that Grandeur in our Garden Waterworks in England, as they are in France or Italy, &c. Mr. Addison, whose Remarks on Men and Things has been so justly admired, says, p. 45. of the late Edition of his *Travels*, that though the Italians fall short of the French in their Gardens, yet that it must be said, to the Honour of the Italians, that the French first took from them the Plans of their Gardens, as well as Waterworks; so that the surpassing of them at present is rather to be attributed to the Greatness of their Riches, than the Excellence of their Taste. The

Cascades of Italy, which are generally natural, or contrived agreeable to it, are certainly some of the noblest in the World. The *Rosea Rura Velini*, which Virgil mentions in his 7th *Æneid*, is, according to Mr. Addison, a wonderful Thing: "The Channel of the River lies high, and is shaded on all Sides of it by a green Forest, made up of several Kinds of Trees, that preserve their Verdure all the Year. The neighbouring Mountains are cover'd with them; and, by Reason of their Height, are more exposed to the Dews and drizzling Rains, than any of the adjacent Parts, which gave Occasion to the Poet's *Rosea Rura* (or dewy Country.) The River, says our oft-quoted Traveller, runs extremely rapid before its Fall, and rushes down a Precipice of an hundred Yards high, throwing itself in the Hollows of a Rock, the Bottom of which it is impossible to see. In this, says our learned Observer, there is something more astonishing, than in all the Water-works of Versailles."

Of this Cascade, which is not far off from that Part of Italy, which has been called *Italia Meditullium*, which Mr. Addison judges to be the Gulph thro' which Virgil's *Alecto* shoots herself into Hell. Virgil thus sings—

—densis hunc frondibus Atrum
Urget utrinq; latus Nemoris, Medioq; fragosus
Dat Sanitum Saxis & torto vortice torrens:
Hic Specus horrendum & Savi spiracula Ditis
Monstrantur, ruptoq; ingens Acheronte vorago
Pestiferas aperit fauces, queis Conditæ Errinys
Invisum Numen terras, Cælumque lavabat.

Thus



NOTES upon BOOK I.

Thus English'd by Dryden:

————— on either Side
Thick Forests the forbidden Entrance hide:
Full in the Center of the Sacred Wood
An Arm ariseth of the Stygian Flood;
Which falling from on high, with bellowing
Sound,
Whirls the black Waves and rattling Stones
around:
Here *Pluto* pants for Breath from out his Cell,
And opens wide the grinning Jaws of Hell;
To this infernal Gate the Fury flies,
Here hides her hated Head, and frees the
labouring Skies.

To conclude this Note, Mr. Addison is so wonderful in his Description of Rivers, Rural Scenes, and Falls of Water, that I cannot but quote him in the noble Description he gives, from his beloved Poet *Virgil*, of the Lake *Benacus*, now *Lago di Garda*.

*Adde lacus tantos te Lari Maxime, teque
Fluctibus & fremitu assurgens, Benace, Marius.*

Here vex'd with Winter Storms *Benacus*
raves,
Confus'd with working Sands and rolling
Waves;
Rough and tumultuous like a Sea it lies,
So loud the Tempest roars, so high the Bil-
lows rise.

At the lower End of this Lake lies the
Mincio; of which *Virgil*. *Georg.* 3. thus:

————— *Tardis ingens ubi flexibus errat
Mincius & tenera praelexit Arundine ripas.*

Thus Englished by Dryden.

Where the slow *Mincius* through the Valley
strays:
Where cooling streams invite the Flocks to
drink,
And Reeds defend the winding Waters
Brink.

Claudian's Larius is by Mr. Addison sup-
posed to be an Imitation of *Virgil's Benacus*.

————— *Umbrosa vestit qua Littus Olivâ
Larius & dulci mentitur Nerea fluctu.*
De Bell. Get.

The *Larius* here with Groves of Olives
crown'd,
An Ocean of fresh Water spreads around.
Thus far Mr. Addison.

Chap. I. Pag. 11. *The Villa de Medicis, with its Waterworks; the Cascade of the Fe-
verone, with the famous Falls of the Fres-
cati, &c.*

I must own myself a little concerned, that two such great Authors as Mr. Addison and Mr. Misson, should have such different Ideas of the Waterworks of Italy, as they have: The first speaks of them in the loftiest Manner; but the last, as it were, with Contempt, in respect to those of *Versailles*; but as this might proceed from the particular Attachment that the latter had to the Interest and Glory of his Country, his Partiality may be in some measure excused; since, by all the Prints I have seen, it appears, (whatever Esteem we put on those of France) that the Waterworks of Italy are much more rural and grotesque, than those of France.

Misson, Vol. II. p. 63. says, He is sorry that he cannot relate such Wonders of the *Tivoli* and *Frescati* as his Friends might seem to expect: And a little after, that the Gardens and Waterworks of the *Belvedere*, the *Villa Ludovisia*, &c. deserve to be compared to *Versailles*, as *Frescati* to Rome, or two or three Trees to a fine Landskip; though he gives a pretty good Encomium on the Cascade of the *Villa Ludovisia*. And p. 66. he tells us, that the Waterworks of *Versailles* (an extravagant Way of comparing Things) exceed a thousand Times those of *Tivoli*.

The Cascade of the *Teverone*, or the ancient *Anio*, he says, is the most remarkable Thing in this little Town; that the River forms a pleasant Sheet; but the Fall (though *Horace* and *Silius Italicus* call it *Præceps Anienus*) is not high; and indeed by the Prints I have seen, it is not above four or five Yards at most; near to which is that made by the late Duke of Kingston at *Thoresby*, *Nottinghamshire*, &c.

But although I have been somewhat displeas'd with Mr. Misson for the contemptuous Account he gives of the Waterworks of Italy (in Opposition to Mr. Addison, who will always be the Favourite of the English Nation, yet I could not but like the Description he has given of the Fall of the River *Velino*,

NOTES upon BOOK I.

Velino, which he paints, if possible, in stronger Terms than Mr. Addison himself has done; for which see p. 363, 364, and 365, Vol. I. Part 2. of *Misson's New Voyage to Italy*: All which may be summ'd up in the Account that *Athanasius Kircher*, in his Treatise call'd *Mundus Subterraneus*, Lib. 2. Paragr. 4. Pag. 115. Col. 1. sets down. Let me use his own Words.

Fluvius summo impetu in modum Areas ruens in profundum voraginem, Altitudine circiter pedum uti ex Dimensione Rupis à me facta patuit. Examinatis itaque omnibus institutio meo opportunis Catadupa circumstantiis inter amnam reversus.

I might (from Authors who have wrote of the *East* and *West Indies*, and other Parts) have added what they have said of such precipitate Cataracts of Water, but that I fear I shall thereby tire my Reader.

The Nile (as *Varenius* in his *Geograph. General*, Cap. xvi. Prop. x. has it) falls from between two Mountains so great a Height, and with such Force, that it is said to make the Inhabitants deaf; and the *Wolgda* (not the *Volga*) a small River of *Muscovy*, has two large Cataracts near *Ladoga*. The River in the Kingdom of *Congo* has one, where the Water falls from the Top of a high Mountain; as has the *Rhine* near *Bilefelda* and *Scaushausen*: Nor are we altogether wanting of our natural Falls of Water in *Great Britain*; since I am well inform'd by the ingenious Sir *Robert Cotton*, that there is somewhere in *Wales* a Cataract, or Fall of Water, of a Height equal, if not exceeding any yet mention'd, that runs down with continual Violence.

Chap. II. Pag. 15. Line 1. For that of Aristotle and his Followers, &c. This Opinion of Aristotle and his Followers is related at large by *Varenius*, pag. 224. of his *Geograph. General*. in the following Manner. Aristotelici sequuntur opinionem Præceptoris sui Aristotelis, quod aqua fontium generetur ex Aere in terræ visceribus contento. Rationes adducit has: 1. Ex aere supra terram existente aquæ generantur, pluvie nimirum: itaque cum in terræ visceribus & aer sit & eadem condensationis causa, nempe frigus, ideo absurdum esse dicit, si quis non putet ibi quoque ex aere aquam fieri. 2. Experientia testatur. quod in terra grandiores guttæ ex parvis factæ stillent, & ideo fluviorum principia esse quasdam veluti scaturigines aquarum, quæ in unam aliquam terræ partem concurrant.

Ideo enim, qui aqua ductus struunt, scrobibus atque cuniculis aquam deducere, tanquam ab excelsis sudante terra solent. 3. Quia pluri mi fontes, & quidem maximorum fluviorum in locis montanis reperiuntur, pauci in locis planis, &c. For which also see Aristotle's first Book of *Meteors*, Chap. 11.

Chap. II. Pag. 15. Line 4. As a learned Physician, in a Manuscript, &c. This Physician, who has quoted the Opinion of *Aquinas*, *Scaliger*, *Faber*, &c. was the learned Dr. *Chamberlayne* of *Shaftsbury*, *Dorsetshire*, who has left in the Hands of his Daughter, Mrs. *Mary Climpson* of *Hungerford*, *Berkshire*, a large Volume in Writing of conjectural Philosophy, in which he appears to reason excellently well on all those difficult Points.

Chap. II. Pag. 15. Line 20. *Faber* from the Attraction of all Waters by the North Pole, &c. This Opinion had its Rise, in all probability, from the general Eruption of Springs out of the North, rather than out of the South Sides of Hills, as is obvious to any (even the most incurious) Observer. Thus *Varenius* says of them, *aversi sunt solis cursui*; and just after, *ipsique montes suas habent umbras obstantes, ut radii Solis non directè perveniant ad terram, nec possint humores exsugere*. Prop. xxii. Cap. 16.

Chap. II. Pag. 16. Line 10. Whence, according to the Opinion of some of the best Philosophers, both ancient and modern, it had its first Rise. In the Solution of this, see *Varenius* also, who, from many weighty Reasons, some of which follow, concludes, *Quod terram, quicquid aquarum ex ostiis fluviorum in mare emisit, rursus accipere. Occulto enim itinere maris aquam subire terras, & in transitu per multiplices anfractus terrarum verberatum & per arenas atque argillam colatum deponere salsedinem & amaritudinem, & sic in sinceram aquam transire*. And, says he, this I believe to be true, though I don't altogether deny other Causes; for that above a thousand Rivers empty themselves into the Sea; and, to give it in his own Words, *Rationes sunt hæ: 1. Quia plures quam mille fluvii in mare se exonerant, & majores ex illis tanta copia, ut aqua illa, quam per totum annum emittunt in mare, superet totum Tellurem, sicut Wolga in mare Caspium, & alii. Itaque fieri aliter nequit, quin ex mari aqua in plurima Telluris loca, & usque ad fluviorum*

NOTES upon BOOK I.

fluviorum fontes emittatur. Nisi enim hoc fieret, ne cogitari quidem potest, quomodo mare non augeatur in immensum, vel cur fontes non desinant emittere aquam. Neque dicas, vapores tam multos è mari elevari, quam aqua mare acceperit à fluviis, &c.

Chap. II. Pag. 16. Line 27. *Tho' those Veins, Channels, and Ducts of Earth, &c.* That there are such Veins is evident from all heterogeneous and different Bodies, such as Scollop, Mussel, and Oyfter-Shells, which are found in the Bowels of the Earth very distant from the Sea. Of the same Kind also is that Mast, which was (as Dr. Plott, pag. 108. relates) dug out of the Top of an exceeding high Mountain in *Greenland* with a Pulley join'd to it; but this is not to be compared to what *Baptista Fulgosa*, *Ludovico Moscelli*, and *Theodoro Moretto*, Anno 1460. relates of a Pit near *Verona*, that was fifty Fathom deep, out of which was dug a whole Vessel, with Anchors and broken Masts, and in which were also the Corps of forty Seamen and others.

Now, tho' some of our ingenious Theorists, in the Account they give of this heterogeneous Mixture in the Bowels of the Earth, attribute all this to the Deluge, which they say dissolv'd all the World into a Kind of a Pap; and that every Thing then sunk deeper or shallower, according to its specifick Gravity, and so Scollop and other Shells may sink with them; yet this Deluge was so very long ago, that it was improbable these Things should remain so long unconsumed: The Account of the Ship especially; which is attested by many grave and serious People, could not be then, in all probability, sunk; because Navigation was not then known, nor 'till the Ark was made, no Vessel of that Kind was ever seen; so that, in all probability, the Vessel here mentioned was drove up through the Syrtes or Quick sands of the proximate Shores, into these Veins and Hollows of the Earth, as it is related by *Andrew Moralis*, *Decad. 7. cap. 8.* of the Gulph of *Charybdis*, near the *Sicilian Sea*, over-against *Sylla*, where Abundance of all Kind of Things are found; the Water there whirling about with such a Force, that tho' they endeavoured all they could, yet they could hardly keep the Ship they were in from being swallowed up.

And of this Kind Dr. Plott (pag. 111.) produces a great many more, amongst the Islands of *Mosko*, *Weroe*, *Roost*, and *London*, in the *Norway Shores*, call'd by some the *Monsk*: This *Homer* calls *Ομφαλος Λαλαωνος*; *Umbilicus Maris*, by *Paulus Diaconus*; *Anhelitus Mundi*, by *Mela*; *Nares Mundi*, by *Solinus*; *Acheron*, by *Suidas*; *Τάρταρος*, by *Pluto* and *Aristotle*; one of which, as *Abraham Ortelius* in his *Geographical Treatise*, under the Word *Umbilicus*, says, was forty Miles in Circumference, and so sa-
perfuse in the Summer, that it appeared like a Sea itself, and which, with a horrible Noise, at once overwhelm'd Ships, and whatever else came thereinto.

Chap. II. Pag. 16. Line 36. — *That give another Reason for their Origin and Rise, attributing it to Vapours, and not Air, &c.* Of an Opinion something of this Kind was *Cardanus*, as the same *Varenius*, pag. 221. of his oft-quoted Treatise sets down in the following Words:

Cardanus cum aliis censet, aquam fontium fieri à rivulis, quæ ex aqueis vaporibus tam intra quam extra terram existentibus & condensatis generati sunt, sed fontes solos vix efficere fluvios, nisi pluvia vel resolutæ nives accedent. Rationes ejus sunt. 1. Si montes mane invisas, humidus invenies. 2. Fluvii matutino tempore excrescunt & quidem eo magis, qui fonti prior pars ejus sit.

But *Varenius* himself soon turns the Scale against both these Philosophers, by saying, *Verum perpetuus & constans profiliens ex fontibus aqua impetus non videtur à tam imbecilli causa & inconstante ortu habere. Neque differt hæc Cardani sententia multum ab Aristotelica, nisi quod Aristoteles aerem cum generatione, Cardanus vapores sine generatione ponit causam fontium, & vero exigua est inter aerem & vapores differentia.* See *Lib. 1. Prop. v. Art. 4.* of *Varenius's Geography* before said.

Chap. II. Pag. 23. Line 1. *That in a Year there might commonly fall in Rain-Water to the Height of 17 Inches.* The different Depths of Rain, one Year with another, if it was to stagnate on the Earth, the curious and inquisitive Mr. *Derham* has, in the *Transactions of the Royal Society*, and in his Notes
T on

NOTES upon BOOK I.

on his *Physico-Theology*, pag. 23. thus stated. At *Townly* in *Lancashire* 42 Inches and an half; at *Upminster* in *Essex* 19 Inches and a Quarter; at *Zurich* in *Switzerland* 32 Inches and a Quarter; at *Paris* in *France* 19 Inches; and at *Lisle* in *Flanders* 24 Inches.

Something agreeable to this are the Observations of an anonymous *French* Author, which *Dr. Plott*, pag. 62. of his *Teutamen de Origine*, &c. so often mentioned, who took the Course of the Sun from the Head of that River at *Ainay le Duc*, where another small River joins it; and found (*communibus annis*) as himself expresses it, that the

In.

Rain-Water amounted to 19:2 Lines $\frac{1}{3}$ d. from which he pronounced, that it equall'd 280899942 Measures *French*, which *French* Measure is as 83 to 68 Hogsheads and 42 Gallons *English* of Beer, or Ale, lawfully stamp'd; for a *French* Measure, according to *Plott*, contains 16777 $\frac{216}{1000}$ cubick Inches

Gall.

English Measure, which makes 59 $\frac{421}{1000}$ of a Gallon, which is near 49 Gallons and a half: So that a *French* Pipe scarce contains $\frac{2}{3}$ of an *English* one.

This being premised, if one cubick Inch of Water will (according to that Author) produce 83 Hogsheads *French*, or 68 *English* in a Day; then 1200 Cube Inches, which is the Measure of the River of the *Gobelines* near *Versailles*, will produce 99600 Measures; and, in one Year, which is near 366 Days, it will give 36453600 Hogsheads *French*; which, if you subtract from 280899942 Hogsheads, which fall annually in the Conservatory, or Tract of Land, there will remain 244446342 Hogsheads; which is six or seven Times as much as is taken in for the Supply of the River; which he supposes is more than enough for the Nourishment of Plants, the Supply of Vapours, the Exercise of Rivers, &c. For this see his Treatise *De l'Origine des Fontaines, seconde Partie, a Page 189 ad Pag. 207*. Tho' this is found to be deficient at *Willow-Bridge*, which is elsewhere intimated.

To proceed, *Jo. Baptist Ricciolus*, in his *Almegisto Novo, Lib. 2. Cap. 13.* tells us, That the *Eridanus*, or *Padus* in *Italy*, which

is 1000 Paces wide, and 15 Foot, or 3 Paces in Depth, 18000000 cubick Paces of Water every Hour, that is, 432000000 in a Day, and 15552000000 in a Year. And if the *Padus* in *Italy* affords so much, the River of *St. Lawrence*, which is 60 Times broader, and, in all Appearance, much deeper, must produce 933120000000 in a Year of cubick Paces of Water: all which I mention because I would state the Case as fairly as I possibly can.

To illustrate this, I beg Leave to add an Account which I find in the Histories of *England*, by which it is (I think) apparent, that Rains can have little or no Manner of Effect in the Supply of Springs: For how else should it happen, that the *Trent*, a large River which rises in the County of *Stafford*, (as *Knighton*, in his Treatise *de Eventibus Angliæ, Lib. 2.* sets down) which was observed at *Nottingham*, Anno 1110, in the Reign of *Henry I.* that the whole River was dry of a sudden, from early in the Morning to about Three of the Clock in the Afternoon. I say what else could it be from, but that the subterraneous Ducts, which were to supply the Springs, (for there had been no Droughts that any Body had observed) were by some fortuitous Confusion so disorder'd, that they could not supply any more Water, until those Confusions, or the Obstacles that hindered it, were removed by proper Powers, or till the Waters should seek another Way. Four Years after that, (*viz.*) in the Ides of Oct. 1114, as *Simon of Durham* and *John of Brompton* have deliver'd it down, the *Vaga*, or *Medway*, was so dry for some Miles, that for two Days it would not carry even the smallest Boat; for which see *Simon of Durham's De Rebus Gestis, Ang. and Chronicon* in Anno 1114. The same Thing also writes *Matthew Paris* of the River *Thames*, which was so stopped for two Days, that the Sea also retracted, or shrunk back from the Shore; and other Authors add, that Boys could pass on Foot from the Tower to *London Bridge*; and even under the Bridge itself were scarce up to the Knees. Neither, in the mean Time, do the Writers speak of any Want of Showers which cause these Events. This one indeed might be the Reason, that the Tides had first failed sending up their Supply, and then of Course the Springs must fail.

NOTES upon BOOK I.

Chap. II. Pag. 28. Line 28. *An Errata:*
Read, There are small Veins of Water,
which belong, and send the Water to those
which lie lower (*instead of higher*).

Chap. II. Pag. 29. Line 18. *Read,* And
don't contribute much (if at all) to the In-
crease of Perennial Springs.

Chap. II. Pag. 29. Line 30. ——— *they*
would be obliged to go above a hundred Yards
deep before they come to Water. I add to this
an Observation which the Reverend and
Learned Mr. *Derham* has collected from
some skillful Workmen, whose Business it
was to dig Wells in *Essex*: The Ground be-
ing a Clay, after they had dug fifty Foot
deep, the Man in the Well observed the
clayey Bottom to swell, and begin to send
out Water; and stamping with his Foot to
stop the Water, he made Way for so sud-
den and forcible Flux thereof, that before
he could get into his Bucket, he was above
his Waste in Water; which soon ascended
to seventeen Foot higher, and there stay'd.
And altho' they often, with great Labour,
endeavour'd to empty the Well, in order
to finish their Work. yet they could never
do it, but were forced to leave it as it was.
Vid. the Reverend Mr. Derham's Physico-
Theology, cap. 24. pag. 77.

And from hence I would observe, that
if Rains, &c. were the Cause of this vio-
lent Eruption of Springs, they would lie a-
bove the Beds and Strata of the Clay, rather
than under them, (as indeed all Land-Springs,
which have their Original from Rains, yet
seldom or never flow, do); so that it is
plain they come from a deeper Cause, (*viz.*)
from some subterraneous Tubes, out of
which being releas'd, by digging away the
Strata and Beds of Clay above them, the
Flux of Water is so immediate and large.

Chap. II. Pag. 30. Line 39. *And if it be*
made appear, (as I think it is) that cold Wa-
ters are not produced by Rains, &c. Our oft-
quoted *Varenius, Lib. 1. Cap. 17. Prop. xi.*
tells us of a Fountain, not far from *Vienna*,
of that Coldness, that it swells the very
Mouths of those that drink it; neither can
a Man hold his Hand in it; that it is not di-
minished, when the Water is endeavour'd
to be drawn out, nor increased, when there

is any put into it: And that there are in
Troglodidiente Arabia or *Æthiopia*, some
Fountains extremely cold, though it be in
the Middle of Summer; and that there are
in *Stiria*, four Miles from *Gratz*, or *Gretz*,
Fountains so cold at the Bottom, that no
Body can draw Water out of them. Now
how this should be, unless these Waters
were detach'd from the Bowels of the Earth,
where there is a Mixture of Nitre and A-
lum, as also of Mercury, Iron, &c. is hard
to conceive. And that this (says my inge-
nious and learned Author) was the Occa-
sion of it, is certain, not only from the
foregoing Causes, but from the Depths of
the Spring; and for the Defect of the Sun's
Beams, and of subterraneous sulphureous
Heat.

To proceed, in the Words of my Au-
thor, *Sunt etiam fontes quidam, qui alterna-*
tim sunt calidi & frigidi in Catalonia lacus,
& fons Salpola hyeme tepidus, æstate frigi-
diffimus. Hoc illi cum multis commune est.
And he gives this Reason, that in the Sum-
mer the Pores of the Earth (through which
she warm Spirits break out) are open, which
are shut in the Winter: from whence it
comes to pass, that those Furnaces which
warm the Water are forced to be hot; and
for that Reason it is, that some Fountains
are warmer by Night than by Day: All
which is, I think, a most convincing Argu-
ment, that these, and other Kinds of Wa-
ter, which might be named, are not deri-
ved from Rain.

Chap. III. Pag. 41. Line 1. — *have deli-*
ver'd it down, from the Foot of a large Hill or
Mountain. And here I cannot but again take
Notice of what the ingenious Sir *Robert*
Cotton has lately told me, of a strange Spring
which falls from a vast high Rock at *Dy-*
sert in *Flintshire*; though it lies, as near as
my ingenious Author could guess, five hun-
dred Yards high; and that in a constant
Stream, or rather Cataract of Water, tho'
it is the highest Ground in all the Country:
Another pregnant Reason why Springs have
not their Original from Rain, but from the
Sea. And this I think proper to precede
the following Account I have from the Hi-
story of *Switzerland*.

NOTES upon BOOK I.

Chap. III. Pag. 41. Line 3. *To all which may be added what I have read in an Account, &c.* The very Account which is here meant I have since met with, and is as follows: "It is believed, (says the ingenious Author of it) that *Switzerland* is much the highest Country of any Part of *Europe*; and two Reasons are chiefly alledged to justify that Opinion: First, the Sharpness of the Air; and, Secondly, the many Rivers-that have their Source in it. Which second Reason is taken from an Hypothesis, That every River takes its Source in higher Ground, than through which it afterwards flows: And it cannot be deny'd, that many large Rivers take their Rise in these Mountains, since there is found (instead of four that I have mentioned in the Account to which this is referred, and that at a small Distance from one another) the Sources of the *Adda*, the *Ticino*, the *Lintz*, the *Aar*, the *Russ*, the *Jun*, the *Rhone*, and the *Rhine*; besides which, one may reckon the *Danube*; for tho' in Strictness it rises without the Limits of *Switzerland*, yet it is but a few Leagues distant from *Schaufhausen*. The *Ill* is another River which has its Rise near *Bazil*; and tho' the Source of the *Adige* be properly in the Country of *Tirol*, yet it is upon the Confines of the *Grisons*. These (being eleven in Number) are the most considerable Rivers in *Europe*, and which all take their Rise in this small Country of *Switzerland*, besides which there is scarce a Valley which has not a River running thro' it. And as this extraordinary Number of Rivers, in proportion to what we find in other Countries of the same Extent, is brought as a convincing Argument of the natural Height of the Country; so it will as naturally suggest the Impossibility there is of Rain being the Author and Supplier of them."

To proceed with this ingenious Author; "The Lakes which are to be found in that Country are not to be omitted; of which he remembers near thirty; some whereof are so considerable, as to deserve the Name of Seas, as they are called in *German*; the Lakes of *Constance* and *Geneva* being near eighteen Leagues in Length, and four in Breadth; and those of *Neuf-*

chatel, *Zurich*, and *Lucerne*, are not much inferior to them in Length: And besides these Lakes in Plains and Valleys, there is scarce a Mountain that has not one on the Top of it, well stored with Fish, by the Sale of which, they make the Inhabitants some Amends for the Loss of the Land they overflow. Upon the whole, (says my Author) I never saw an Inland Country that abounds so much with Water, as this does: Wherever one goes, one finds an infinite Number of Springs, the purest and sweetest I ever tasted. And there is scarce a Field or Meadow, that may not be laid under Water, whenever the Husbandman thinks it necessary for the Good of his Ground." Thus far Mr. *Stanyan*. To which I need but just remark, the great Difficulty there would be for the Maintainers of the Hypotheses of Air, Vapours, or even Rain, for the Supply of such a Number of great Rivers, Lakes, and Springs, and in so small a Country, as that is. To this I may add what *Seneca*, and others, amongst the ancient, as well as some modern Philosophers, have asserted of the Depths which Rain-Water sinks into the Earth in any Place, especially on Hills, where it runs off with a much swifter Current, than from slow declining Lands. *Jam pluviae maximæ non ultra decimum pedem in terram penetrant.* And an anonymous French Author, in a Treatise *De l'Origine des Fontaines, Partie seconde, p. 167.* (who had made a curious Enquiry into this Matter) affirms, it does not sink a Foot and a half; and all, or most of the Rains which fall in Plains, are consumed in the Nourishment of Plants and Herbage.

Chap. III. Pag. 41. Line 30. *The last Thing to be examined in this Narrative of Springs, &c.* This is sufficiently express'd by Dr. *Plott*, pag. 70. in his Treatise of *Fountains*; to which he adds, *Nam si qua experimentis fides est habenda, vapores qui in auras exhalantur ad nubes, & qui in pluviis demittuntur, non tam è mari originem ducunt, quam à terræ Madere; atque hoc Pacto in Uliginosis & Palustribus regionibus qualis est Hibernia Nimbi non sunt frequentes, enim in aridis Africæ & Arabiæ solitudinibus, vel nulli sunt, vel rarissimis ut mittam quanta cum difficultate; Aquæ saluginosæ, preparationem subeant, aut pluviis magis assiduas ex oriente* &

NOTES upon BOOK I.

et meridie provenire; id est, à continentis non oceano. Huc accedit imbres vehementissimis terræ meatus obtinere, adeo ut susquipedem subsidere non possint, adeoque maximam partem diluviis abstrahuntur: unde adhuc evidentius aquet, quam parum probabile sit fontes tantæ magnitudinis (quantum memoratas diximus) à pluviis in tale conservatorum decidentibus suppleri. All which I thought proper to set down in the Author's own Words, leaving the Decision of it to the curious Reader.

Chap. III. Pag. 44. Line 4. *The Existence of subterraneous Fires, if any such there are, &c.* That there are subterraneous Fires, or rather that there is a Kind of Respiration of warm Air through the whole Mass of Earth, seems to me more and more probable; though whether this Heat resides in the Center, and so disperses itself; or whether that Heat is innate, as proceeding from certain igneous Effluvia's, that are dispersed here and there, is not certain: But from the Warmth there is in Cellars, as also that when you pump a few Strokes with any Engine, so that the cold Water goes off, after which, follows that which is warmer; 'tis certain, I say, that there is such a Thing in Nature.

These Fires break out, as *Robault* in his *Physicks, Part 3. Cap. 9.* says, like those which proceed from *Heclâ* in *Islandia*, or *Ætna* in *Sicily*, or *Vesuvius* in *Campania*; nor are they any other than those which we blow up with our Bellows: But he confesses, that he is not able to explain their Nature. And yet *Dr. Woodward*, in his *Essay, Part 3. Consect. 13.* says, "That there are scarce any Countries that are much annoy'd with Earthquakes, that have not some of these fiery Vents; and those (says he) are constantly all in Flames, Whenever any Earthquake happens, they disgorging that Fire, which whilst underneath was the Cause of the Disaster (with more to the same Purpose) and concludes; In one Word, says he, so beneficial are these to the Territory where they are, that there do not want Instances of some which have been rescued, and wholly delivered from Earthquakes, by the breaking forth of new Volcano's there; this constantly discharging that Matter, which

"being till then barricadoed up, and imprisoned in the Bowels of the Earth, was the Occasion of very great and frequent Calamities." Thus far *Dr. Woodward*. The Uses that these Volcano's, or the innate Heat which labours in the Ground, is certainly to lessen or take away the Weight of Air, which is mixed with the Earth, so that the Water may ascend the freer, even as we see it in the *Æliop. le Terr. Sigma, &c.*

Chap. III. Pag. 49. Line 5. *Errata.* Instead of, not being explained, read, not being irregularly explained by the rising of Water in a smaller Pipe.

Chap. III. Pag. 50. Line 3. *It is not much to the Purpose to examine, or confute the Opinion of those who affirm, that the Depth of the Sea is no more in Perpendicular, than the Height of the Mountains above it.* The Profundity of the Sea, according to the Opinions of the most celebrated Geographers, is various; sometimes $\frac{1}{80}$, $\frac{1}{40}$, $\frac{1}{20}$, $\frac{1}{10}$, $\frac{1}{4}$, $\frac{1}{2}$ of a Mile, &c. And in some Places where the Rope wont reach, they suppose it not less than a German Mile in Depth: But these Geographers don't deny but that in the Bottoms, those Depths there may be Gulphs or subterraneous Meanders, thro' which the Water may pass.

To use *Varenius's* own Words, *In finibus maris profunditas multo minor est quam oceani, qui Alveus est minus profundus sive minus excavatus, propter viciniam terræ sicut eandem ob causam oceanus ad littora minus est profundus quam in remotis terræ locis quod accidit ob solam Alvei ejus figuram cavam.*

Chap. III. Pag. 51. Line 10. *To pass by then all the curious Definitions of the Attraction here spoken of.* *Robault* in *Part 1. cap. 2. Paragr. 15.* seems to be very silent as to Attraction, Sympathy, Antipathy, and the like, on the Account of their Obscurity; and tells us, If you behold a Loadstone, it is plain that there is in it an attractive Power, or, he would have said, a very great Sympathy between it and Iron; but that he could neither explain the Nature nor the Properties of it.

But our learned *Newton*, who has been so great an Honour to his Country in discoveries

NOTES upon BOOK I.

coveries Philosophical and Mechanical, puts the Question, pag. 322. of his *Opticks*, Whether, or no, the small Particles of Matter have not certain Virtues, Force, or Powers, which, by means of something thrown between them, they mutually join to one another, to the Introduction of most of the Phænomena's of Nature: Let me use his own Words, as it follows, what I have translated from him, *Satis enim natus est, corpora in se invicem agere per attractionem gravitatis, &c.*

Chap. III. Pag. 53. Line 1. *That the Sea and many large Rivers are higher in some Places, than the general Level of the Earth, &c.* The Truth of the Proposition, *Varenius* also testifies in *Cap. 3. Prop. i, ii.* from the famous geometrical Proposition of *Archimedes*, which is not found demonstrated in his Elements, but the Solution of which he himself has undertaken, (viz.) *Let any Superficies be cut by Plains passing thro' any one Point of it, and let every Section of the Periphery of the Circle, having that Point for its Center, that Superficies must be spherical, whose Center shall be the Point before spoken of.* And to this Sphericity of the watery, as well as earthy Frame of the World, he pre-joins, That it is the Nature of all Liquids, that their Parts being of an equal Distance from the Center of the Earth, and lying and continuing one amongst another, the lesser Weight is expelled by the greater; for that every Part of a Liquid is pressed by that which is perpendicularly (in Respect to the Center of the Earth) above it; and that Liquid so descending is pressed by some other Body. And he concludes that first Proposition in these positive Words; *Oceani itaque superficies est spherica habens idem centrum, quod est terræ centrum: quod idem etiam ex sequentis propositionis confirmatione manifestum fiet.* And in Proposition the second he does not seem to endeavour to urge or prove that the Earth is lighter than the Sea; but that the Ocean is not of a greater Height than the Banks or Bounds of the Earth: And he concludes (contrary to what *Robault* and others have set down on this Subject) *Atque ideo terra & aqua ejusdem fere sunt Altitudinis ubique exceptis montibus excelsis.*

The Middle of the Sea does indeed look

as if it was much higher than the Land, as whoever approaches the same may discover; though this, I, and many other Authors doubt of: And the most I would endeavour to prove from the foregoing Argument is, that when the Waters, in the Scripture Phrase, are gathered together, (as they are in high Tides) then, if not always, the Middle thereof is as high as the approximate Shores, or Banks of Land-Hills, very high Hills excepted; which will be more fully explained by the following Note.

Chap. III. Pag. 55. Line 19. *But that the Sea in general (at least the middle Part of it) lies rounder than the Land, &c.* This is agreeable to what has been set down in the foregoing Article; and I would endeavour to infer no more from it in this, than that by the Congregation of the Waters, and their Concussion together, by the Gravitation of the Atmosphere, which presses upon them, and forces them towards the Shore, Water may, by the Laws of Hydrostaticks, (and other Powers just mentioned) rise with great Ease to the Tops of high Ground: For I do not aver (as some have) that the Sea is higher, but that it is as high as the general Part of the Land is; nor do aver, in this, that the Spring there mentioned rises on the Top, but rather the Middle, or more lower Part of the Hill.

Chap. III. Pag. 59. Line 22. *But if we consider the Flowings of the Tide, &c.* Here I observe, that if, according to the System of *Copernicus*, with whom *Kepler*, *Gallileo*, and almost all of our modern Philosophers (tho' different from the exact Letter of the Bible) agree, that the Earth turns round upon its own Axis, and that the other Planets are fix'd and immoveable; amongst other Reasons, too many here to be named, for that the Course which the Sun must take is so many thousand Miles more than the Rotation of the Surface of the Earth, how great must that Shock be, which the Water receives by such a Rotation or Revolution; and though it does not (by the vast Number of Miles, of which the whole Circumference of the Earth is, together with its regular and uniform Movement) overturn Houses and Steeples, or put Men in Danger who are walking thereupon; yet Water is of so voluble a Nature, that it is not difficult

NOTES upon BOOK I.

difficult to conceive how much it will force its Way up thro' the Crannies of the Earth, by such a Movement, as when the Sea is, as it were, diametrically opposite, perpendicular, or sloping to the Place, to which the Water is to pass.

Chap. III. Pag. 59. Line 23. *How greatly must such a Rotation contribute to the forcing the Water, &c.* This Observation is what I have not met with in any Account I have ever read of Springs, tho' it does not seem to be an improbable Conjecture; for, if the *Copernican* System holds good, which there is a great deal of Reason to believe it will, (*viz.*) *That the Earth makes a diurnal Rotation round its own Axis, and a periodical Revolution round,* how greatly must such a Rotation contribute to the forcing of Springs out of the Chasms and Fissures of the Earth? And the Imperceivableness of its Motion is a great Demonstration of the Truth of this Supposition, than if it were quick and visible. If you put Water into a Bowl, and swing the Bowl about with great Celerity, the Water wont indeed be much of it lost; but if its Motion was to be leisurely, to what Place is it that it will not find its Way? And why may we not suppose, that it is by this Means that Water issues out of such Hills as it does, by or through those Ducts or Channels, that Nature has formed for that Purpose.

Whoever will be satisfy'd of the Probability of the *Copernican* System, before that of the *Ptolomean*, may have Recourse to the Works of *Rheticus*, *Kepler*, *Rothman*, *Landsberge*, *Gassendus*, *Gallileo*, and others; but more particularly to the Reverend and Learned Mr. *Derham*, in his Preliminary Discourse to his *Astro-Theology*, pag. 7.

Chap. III. Pag. 61. Line 32. *It will not be improper to take a short Survey of what Authors have said of that Deluge.* Of the Eruption of Springs out of Hills, besides what the Scriptures have said concerning the Formation of the World, and of this Deluge, *Ovid*, Cap. 1. Pag. 2. Line 38. thus has it.

*Jussit & ambitæ circundare littora terræ,
Addidit & fontes, immensæque stagna lacusq;
Flumina obliquis cinxit declivia ripis;*

*Quæ diversa locis partim sorbentur ab ipsa;
In mare perveniunt partim, campoque recepta.
Liberiores aquæ, pro ripis littora pulsant.*

But when he comes to give an Account of that fatal Eruption of Water, with which the World was drowned, the Poet is so wonderful plain in his Distinction between the Rain from above, and the Deeps below, that one would think he had consulted Holy Writ itself.

Nec Cælo contento suo Jovis Ira.

And a little after, speaking of the Deeps;

—— *Vires effundite vestris:*
*Sic opus est. Aperite Domus: ac mole remota.
Fluminibus vestris totas immittite habenas.
Jusserat, hi redeunt, ac fontibus ora relaxant,
Et defœnato volvuntur in æquora cursu.
Ipse tridente suo terram percussit: at illa
Intremuit, motuque sinus patefecit aquarum
Exspatiata ruunt per apertos flumina campos.*
Ovid. *Metam.* lib. 1. cap. 1. v. 277. &c.

Virgil, tho' he has wrote nothing direct (at least that I have met with) concerning the Original and Rise of Springs, yet he has left several short Hints of his Opinion on this Head, where he always, however soft his Subject was, talks of nothing but its precipitate Eruption.

Thus Georg. lib. 1. v. 203.

Atq; illum in præceps prono rapit Alveus amni.

And Georg. lib. 3. v. 428.

*Quidum amnis ulli rumpuntur fontibus & dum
Vere Madem udo terræ.*

And Æneid. lib. 1. v. 105.

—— *insequitur cumulo præreptus aquæ mons,
Hic summo in fluctu pendens: his unda debiscens
Terras inter fluctus aperit.*

Chap. IV. Pag. 65. Line 20. *Natural Histories produce an infinite Number of such Springs, &c.* I might have produced a much larger Number of such Springs, in Confirmation of this Chapter: Such are the Fountains near the Lake *Ascanius*, which, as
Agricola

NOTES upon BOOK I.

Agricola says, *Lib. 3.* of his Book *De Natura Rerum quæ effluunt ex terra*, are dry in the Winter, but are filled up to the Brims in the Summer. The same he relates of a Fountain *ad Calidas Lucenses*, to use his own Words, *qui per totam æstatem a Maio ad Septembrem usque uberrime secturo, deinde sic subducere.* *Geo. Weanerus* (as *Dr. Plott* has it) says the same Thing of another in *Helvetia* — *qui semper Augusto mense are-scit; nec ante Junium insequentem rursus e-mergit.*

Chap. V. Pag. 77. Line 12. *In the following Places Springs are certain and good.* The Reverend and learned Mr. *Derham*, who, for the Justness of his Observations, is so much admired, says, in his *Notes Book 3. Cap. 2. Pag. 65.* of his *Physico-Theology*, That it is not only agreeable to Reason, but as he was told by Persons conversant in digging of Wells throughout the County of *Essex*, where he lived, that the surest Beds in which they found their Water were Gravel, and a course-colour'd dark Sand, which Beds seldom fail'd to yield Plenty of sweet Water: But for Clay, they never find Water therein, if it be a stiff strong Clay; but if it be lax and sandy, sometimes Springs are found in it; yet so weak, that they will scarcely serve the Uses of the smallest Family. And sometimes they meet with those Beds lying next under a loose black Mold, (which by their Description he judged to be a Sort of Ouze, or to have the Resemblance of an ancient Rushy Ground,) and in that Case the Water is always naught, and stinks. And lastly, another Sort of Bed they find in *Essex*, in the clayey Lands, particularly in that Part called the *Rodings*, which yields Plenty of sweet Water, (and that is,) a Bed of white Earth, as tho' made of Chalk and white Sand. This they find after they had dug thro' forty (or more) Feet of Clay; and it is so tender and moist, that it will not lie on the Spade, but they are forced to throw it up into their Bucket with their Hands, or with Bowis: But when it comes up to the Air, it soon becomes a hard white Stone. And thus much, says my Reverend Author, for the Variety of Beds wherein the Waters are found. And that it is in these Beds only, or chiefly, the Springs run, is farther manifest from the forcible Eruption of the Waters out of those watery Beds: And this Erup-

tion, says he, shews, that the Water comes from some Eminence, or other, lying at a Distance, and being closely pent up in the watery Stratum, by the Strata of Clay, the Waters with Force mount up.

Chap. V. Pag. 81. Line 27. *When you have pitched upon a Place that is proper to bore for Water, &c.* Those who have wrote of the Formation of the Earth, say (*Vid. Steno's Prodrum.* and *Dr. Woodward's Essay, Part 2.*) that when the terraqueous Globe was in a chaotick State, and the earthy Particles subsided, then these several Beds were in all probability repositied in the Earth, in that commodious Order in which they are now found; and that is as asserted according to the Laws of Gravity. But *Dr. Leigh*, in his *Natural History of Lancashire*, speaking of the Coal-Pits, denies the Strata to lie according to the Laws of Gravitation. In answer to which, Mr. *Derham*, being suspicious that no real Experiment had ever been made of it, try'd it himself, and found, that the Strata in his Yard were gradually specifically heavier and heavier the lower and lower they went; and the upper, which was Clay, was considerably specifically lighter than the lower Stratum, which was a loose Sand and then a Gravel; in which Strata the Springs ran which supply'd his Well. And here it may again be observ'd, that Springs run rather under than above Clay, which they would not do, did they owe their Original to Rain.

Chap. V. Pag. 82. Line 4. *When they dug down such a Pile as I have been before describing, &c.* To this I add what *Monf. Blondell* related to the *Parisian Academy*, concerning the Devices which the Inhabitants of the *Lower Austria* were wont to use when they wanted Water: They dug down to the Depth of 20 or 25 Foot, till they came to an Argille or clammy Earth, which they bored through so deep, till the Waters broke forcibly out; which Water, it is probable, comes (I add) from Springs which rise up in and from the neighbouring Mountains in subterraneous Channels. And *Cassinus* observes, that in many Places of the Territories of *Modena* and *Bologna* in *Italy*, they make themselves Wells by the same Artifice, &c. By this Means also the same *Seigneur Cassini* made a Fountain at the Castle of

NOTES upon BOOK I.

of *Urbis*, that cast the Water up five Foot above the Level of the Ground; as whoever sees Mr. Ray's Discourse, p. 40. may be better informed. And this is a Demonstration, that Water rises first of all into the Tops of high Hills, and after that descends into low Grounds; and not from Rains, which run off so precipitately, that they scarce enter a Foot into the Ground.

Chap. VII. Pag. 97. Line 18. *This new Invention, or, at least, this great Improvement of an old one, &c.* Since the Printing of the foregoing Sheets, I have had an Opportunity of being farther and better informed of the Nature, Size, and Prices of the earthen Pipes I have there recommended.

In the first Place, I observe, that the Undertakers have not as yet made any above three or four Inches Diameter, being a little cautious how they adventure too far at first, though they have some Hopes to make them larger: Neither are they fond of using them on the Outsides of Houses, because they are more liable to be broken there than any where; but they are excellently useful in carrying off Water which is to go down in the Walls or Inside of a House, taking up so small a Column of the Wall, that it does not weaken it.

In the second Place, I observe, that the Cement with which they join them is not such as *Vitruvius* tells us the *Romans* used; but is much stronger, and something of the Nature of that with which Statuaries join on particular Limbs and Parts of broken Statues, &c. And this Cement is not liable to an Objection, which I have heard has been brought against those Pipes, in relation to a Weed, which, with its Fibres, is apt to choak up the Pipe; but this Cement is nevertheless dissolvable by Heat, whenever you have a Mind to repair a broken Pipe: And it is farther observable, that this Cement is so strong, that any other Part of the Pipe will sooner break than the Joint.

In the third Place, I observe, that as there are some, though not very many Pipes in every Kiln, which are a little faulty, and subject to a few Flaws or Cracks, that these Pipes are nevertheless useful, wherever you have great Plenty of Water to supply them;

as is the Case where you lay Pipes to supply Gardens, from the *Thames*, or other large and plentiful Rivers; for there, tho' there is some Waste, yet the great Supply is such, that it will not be minded. And these Kind of damag'd Pipes may be also used, wherever you are to convey Water thro' Drains from the Eves or Roof of a House, Stable, &c. especially if it runs through a Gravel; for there the Sinking-away of Water is of no great Moment.

Having very lately receiv'd the following farther Account of these Clay Pipes, I have been here recommending, I beg Leave to insert it for the Benefit of my Readers, and that there may be nothing wanting that may recommend so useful an Invention.

The Account runs thus:

MR. *William Edwards* of the Town of *Monmouth*, Patentee for the sole Making and Vending of his new-invented Water-Pipes, made of common Clay, by a particular Method, and in a Manner never heretofore practised by any Person but himself.

And by whose Directions they have been so placed and disposed in Buildings, to carry the Water from the Roof and Gutters of Houses, and discharge the Water on the Surface of the Earth, and into the common Sewer.

And likewise he has, by his Servants, laid great Quantities of these Pipes underground, for Aqueducts, that now do convey the Water for Eighteen Hundred Yards in Length, discharging the same Quantity taken in, without the least Waste.

They are allowed by Men of the best Quality, and Gentlemen of the best Taste, in this Way, to exceed Lead or Wood Pipes, both of which are perishable; whereas these will endure Ages to come, or, what may be said, to Perpetuity.

Great Expence and Trouble is bestowed in preparing the Clay; as Pitting, Washing, Ridling, Grinding it in a Mill, Treading it with Mens Feet, and Working it with their Hands into Messes, and then it is form-

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NOTES upon BOOK I.

ed into Pipes upon a Potter's Wheel to any reasonable Substance: When they are dried to a Temper, they are put upon a Mandrel, or Plug of Wood, and turned to great Exactness upon a Turner's Lathe, one End being engrafted into the other, groove-wise, that receives the melted Cement, or Soder so artfully into the Joints, which becomes by it more strong than any other Part of the Pipe, altho' very remarkable for their Hardness, bearing a Fire in their Burning, of the greatest Violence, for five or six Days and Nights successively, insomuch that they become as impenetrable and hard as Flint; and, by the Use of a Steel, you may strike Sparks of Fire from Pieces of them, that will light Tinder, as from Flint.

Considering the great Labour and Expence to bring them about, with the great Quantities that break, by the Violence and any extream Change of Weather, and other Incidents in carrying them to and from the Kiln, as well as their Breakage in it, they cannot be sold for less than the Prices following; two Inch Bore in the Diameter being the least Size made:

	s.	d.
Two Inch Bore (<i>per Yard</i>)	02	00
Three Inch Bore	03	00
Four Inch Bore	04	00
And so on 5, 6, 7, so many Shillings.		

But a second Sort may be made, for Works that require less Strength, and of Clay unprepar'd, and not digested as afore-mention'd, for and after the Rate of 9d. *per Yard* every Inch in the Diameter; that is to say:

	s.	d.
Two Inch Bore (<i>per Yard</i>)	01	06
Three Inch Bore	02	03
Four Inch Bore	03	00
And so on in Proportion.		

All Pipes are try'd upon Delivery; and if any prove crack'd or defective, they are laid aside, to be used in Drains, or in any weak Current of Water, and are sold for half Price as others are.

And to make all these Pipes more effectually good and serviceable, in all Cases and Works whatsoever, Mr. *Edwards* has very well consider'd the Power of Air, as well as Water, and their Operations as confin'd within these Pipes, and has lately found out, contrived, and made Brass Valves, or Clacks, placed within his said Pipes, at a proper Distance, which discharge the Air, and, as the Water prevails, throw up the Clack that confines the Water from issuing out, and prevents all Strugglings in the two Pipes, which takes off two Thirds of that Power, (which is generally called Friction, or rather the Interposition of Air,) and facilitates the Delivery of the Quantities of Water they ought: By which Means he now makes Use of these Pipes to convey Water from Engines of great Force to Reservoirs six hundred Yards in Length, and sixty Foot high; and, as far as I am capable of judging, Mr. *Edwards* has brought them to so great Perfection, that he is able to answer all Objections that can be raised against him: And these Pipes will, I doubt not, be of great Use in many Things not yet thought of, as they are in Cities for Up-stair Bog-Houses, &c.

He has an Art in laying these Pipes in their Work, that if a Sediment of any Sort works into them, he lays in four, five, or six Foot of waste Pipe for a Lodgement for it, which is instantly discharged.

Any Work that's practicable to be done, for 6d. *per Yard*, two Inch Bore, and all as proportionable in larger Sizes, he will insure their Performance.

From the foregoing Calculations of the Prices or Expences of the different Kinds of Piping, I have drawn the Table following, omitting Iron, which are seldom or never cast in small Molds; besides rejecting Alder, Fir, and all those other Kinds of Piping, I draw the Parallel only between the three Kinds so much in Dispute, which are Lead, Wood, or Clay. And, as to the last, I divide them into two Kinds, (*viz.*) those which are the strongest and best burnt, and those which are a little crack'd in the Burning; to which I shall add a third Sort, which were made by my Friend Mr. *Mutchell*, before

NOTES upon BOOK I.

before the Patentee and he had come to any Terms of Agreement, and which will undoubtedly serve in all ordinary leisurely Falls, or at the Extremity of a Force Work.

To this I subjoin, that the Price of the leaden or wooden Pipes are reckon'd naked, and at the prime Cost, without Solder in one or Iron Bands in the other, the Cost of which is uncertain; but still makes the Difference between them the greater. To this I may still add, that the Prices of Lead are

sometimes much greater than I have set down; and tho' it may be said in Justification of Lead-Pipes, that they will sell at last, if any Gentleman has a Mind to it; yet 'tis to be supposed, in Answer to it, that there are few that lay Pipes with any View but to Perpetuity. How long Lead-Pipes will last, without being eat, or worn out by the Earth they lie in, I need not expatiate on; nor need I set down how much Elm-Pipe decays in a little Time, nor how subject they are to burst.

Inch Bore	Lead		Wood		Best Clay		2d Best Clay		Crack'd Clay	
	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
2	6	0	1	3	2	0	1	6	1	0
3	9	0	2	0	3	0	2	3	1	3
4	20s. and upwards		2	6	4	0	3	0	1	6

Upon a View of the above Table, it appears, that the Expence of Clay Pipe does not rise, in Proportion to their Diameter, as Lead and Wood, on the Material, unavoidably does; for a Pipe of Lead of 2 Inch Bore is three Times the Charge as that of the best Clay) whereas a Pipe of 4 Inch Bore in Lead is above five Times the Expence of it in Clay. As to the Expence of the Cement which joins the Pipes together, that is of little Value, and the digging and laying of every Kind is always the same: So that I leave every Gentleman from this View to determine with himself, which of the Pipes are most eligible, supposing that the Clay will sustain any Perpendicular Weight, or even the strongest Stroke of an Engine, which I dare answer they will, especially if you lay 38 or 40 Yards of Iron Pipe next to the said Engine? which is all I have to add in this Affair.

Chap. VI. Line 1. Lib. 6. Pag. 96. *Here follows a Table of the Earth's Curvature, &c.* This Note should have been put in another Place, but that it was in a Hurry overlooked: However, that I may do the utmost Justice I can to the Memory of so great a Man, I shall recite his Opinion on this so Mathematical and useful a Calculation, as it relates to the Curvature of the Earth, and therein the Conveyance of Water from one Place to another.

This ingenious Gentleman, Pag. 58. of

his *Mathematical Compendium*, that in carrying a Stream or River, such as the *New River* from a little above *Ware* to *London*, or elsewhere, you must allow a Foot, or a Foot and two Inches, for a Mile in Descent, or more, if your Fall requires it; and this because of the Tangent from the Surface of the Globe of the Earth in every Mile; and tho' in a Mile it will be found to be but six Inches, yet it is better to hold to the surer Side; tho' later Experience shews, that this great Man was mistaken, for that Water will descend very well in an open Sewer at about four Inches, or four Inches and a half in a Mile's Fall.

But for Common Sewers, or Passages to carry off Water and Dirt in Streets and Towns, for every ten Foot, you ought to allow two or three Inches Fall, or more, if you can, which in every hundred Foot will be one Foot eight Inches Fall. If you allow two Inches, or two Foot six Inches, you allow three Inches; and the more the Fall will allow, the better it is.

This Note I also insert, for that I have by Mistake misrepresented what this ingenious Author says, as to the Descent proper for Water, which Mistakes are to be found pag. 103, 104.

Chap. V. Pag. 83. Line 26. *When you dig for a Well, great care ought to be taken of the Steneing* (not Stewing it, as it is, by Mistake, in the printed Sheet) *the Sides, to keep*

NOTES upon BOOK I.

keep it from tumbling in, but to take care that the Effluvia's of the Water, &c. This is the Direction of the learned Vitruvius, as Varenius tells us from Lib. viii. Cap. 7. and not Lib. x. Cap. 6. is in the Description before-going, which is so particularly set down by those Authors, that I shall finish these Annotations with a full Account of it: *In puteorum autem fossionibus non est contemnenda ratio, sed acuminibus solertiaque magna naturales rerum rationes consideranda; quod habet multa variaque terra in se genera. Est enim, uti reliquæ res, ex quatuor principis composita; & primum est ipsa terrena, habetque ex humore aquæ fontes. Item calores, unde etiam sulphur, alumen, bitumen nascitur, aerisque spiritus immanes; qui cum graves, per intervenia fistulosa terræ, perveniunt ad fossionem puteorum, & ibi homines offendunt fodientes, naturali vapore obturant in eorum naribus spiritus animales: ita qui non celerius inde effugiunt, ibi interimuntur. Hoc autem quibus rationibus caveatur, sic erit faciendum. Lucerna accensa demittatur, quæ si permanferit ardens, sine periculo descendetur. Sin autem eripietur lumen vi vaporis, tunc secundum puteum dextra ac sinistra defodientur æ-*

stnaria, ita (quemadmodum per nares) spiritus ex æstuariis dissipabuntur. Cum hæc sic explicata fuerint, & ad aquam erit perventum, tunc puteus ita sepiatur structura, ne obturentur venæ. Sin autem loca dura erunt, aut in imum venæ penitus non fuerint, tunc signis operibus ex tectis, aut a superioribus locis excipiendæ sunt copiæ. In signis autem operibus hæc sunt faciendæ, uti arena primum purissima asperimaque paretur, cæmentum de silice frangatur, ne gravius quam libarium, calx quam vehementissima mortario misceatur, ita ut quinque partes arenæ ad duas calcis respondeant: mortario cæmentum addatur, ex eo parietes in fossa ad libramentum altitudinis futuræ depressa, calcantur vectibus ligneis feratis. Parietibus calcatis, in medio quod erit terrenum, exinaniatur ad libramentum imum parietum, & ex aquato solo ex eodem mortario calcetur pavimentum ad crassitudinem, quæ constituta fuerit. Ea autem loca si duplicia aut triplicia facta fuerint, uti percolationibus aquæ transmutari possint, multo salubriorem ejus usum efficient. Limus enim cum habuerit quo subsadat, limpidior aqua fiet, & sine odoribus conservabit saporem: si non, salem addi necesse erit, & extenuari.



BOOK

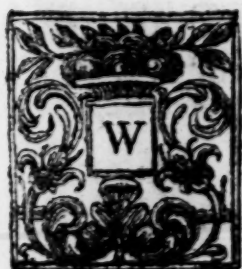


A N
INTRODUCTION
T O A
General SYSTEM
O F
HYDROSTATICKS and HYDRAULICKS.

B O O K II.

C H A P. II.

Of Hydrostaticks, its Etymology, Definitions, &c.



WITHOUT Doubt the Etymology or Derivation of Hydrostaticks, though it is (being a Compound) a Word rarely to be found in any of our Glossaries, (at least in any of those that have fallen into my Hands) is from $\Upsilon\Delta\Omega\text{P}$ or perhaps rather from $\Upsilon\delta\text{ρ}\acute{o}\varsigma$ *Aqua*, Water, or of or belonging thereto, and $\sigma\alpha\tau\iota\kappa\eta$ *Statice*, which signifies a weighing or ballancing, which being join'd together signify the Equipondium, weighing or ballancing of Water and other Liquids; and in this Sense *Marriotte* and other Writers in Hydrostaticks use it, when they discourse of the Equilibrium of Water, and other Liquids and Fluids, by their Gravity, Elasticity, Impulse, and the like.

OZANAM defines Hydrostaticks to be that Part of Mechanicks, which considers the Weight of Liquids, and especially
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of Water, or solid Bodies immers'd into or laid upon Liquids, by comparing them with each other, and that though Liquids are ponderous, nevertheless they have not of themselves a Center of Gravity, because their Parts are not so link'd together as to sustain one another in Equilibrio about one certain Point, unless they are shut up in a Vessel, and then there may be observ'd a great deal of Conformity occurring in Staticks, and Hydrostaticks which will be occasionally explain'd.

FOR as by Staticks, it is known, that the Weight of Bodies encrease according to their Distance from the Perpendicular, just so on the contrary it is known by Experience; in Hydrostaticks that the Weight encreases its Gravity, as it comes nearer to a Perpendicular; but of this more in its proper Place, and to go on.

ALTHO' the Word Hydrostaticks seems in its literal Construction to belong to Water only, yet it is now us'd more generally, and is apply'd to all Sorts of Fluids, as Air, Flame, &c. to which may be added of Liquids, Oyl, Mercury, Wine, Ale, Beer; because all these other Bodies naturally fall within the Compass of Hydrostaticks, though they have not exactly the same Properties as Water has; for Air, Flame, and I may add Sand, are Fluids (as *Marriotte* Part 1. Discourse 1. well defines) Oyl, Mercury, and other Liquors are both fluid and liquid; for every Liquid is a Fluid, but every Fluid is not a Liquid.

BY a Liquid is meant such a Fluid as being in a more sufficient Quantity will flow and extend itself under the Air, till its upper Surface be level, and because Air and Flame want that Property, they are not call'd Liquids but Fluids; so also Hardness and Firmness are oppos'd to Fluidity, because a hard Body, such as Iron and Stone, is pass'd through with much greater Difficulty, than Liquids and Fluids are, and when it is pass'd through, its Parts do not so easily unite and join together again; on the contrary Fluids, such as Air, Water, &c. immediately reunite, and in this it is that Fluidity consists.

So also it is that fine Sand may be call'd a Fluid, but not a Liquid, because it does not run or flow upon an inclin'd Plain, and when a Vessel is fill'd with it, the upper Parts do not of themselves run to a Level so easily as Water does.

I SHALL in some of the following Chapters define and explain the wonderful Properties of Air, and its Uses in Hydrostatick and Hydraulick Motion; but as Water is the chief Thing to be consider'd in this Chapter, it seems requisite I should make the clearest Definition of it I can, in what Manner it is compar'd with

with other Fluids, especially Air, and consider'd of in Relation to itself.

Now by Water is not meant that Part of the Globe so call'd, nor do we build or even consider it according to that of *Archimedes*, who lays it down as a Rule certain *that the whole Body of Water is spherical* (even when it is not moved) *and that its Superfices has for its Center that of the whole Earth*; but in Relation to Air and Water it is necessary to have a Regard as well to certain Things whereof they are capable, as to those wherein they cannot suffer any Accident.

FOR Water, though it may be extended by the Intermixture of Air, or attenuated or converted into Air by the Means of Heat which resolves it, yet nevertheless it can't be press'd; that is to say, that a certain Quantity of Water cannot be forc'd by Compression, so as to be contain'd in less Space then its natural State: Whereas Air, on the contrary, may be restrain'd and put up, when it is press'd or rarified, or mov'd beyond the other Accidents of which it is capable; all which will be demonstrated by Propositions deduc'd from Experience itself in the Course of the ensuing Treatise.

AND to proceed in Relation to Water abstracted from those Properties, there are several others which are produc'd in the Hydrostatick Way of Reasoning, some properly and others improperly.

As first that * Water is call'd moist or humid tho' improperly, notwithstanding *Archimedes* himself in his two excellent Books *de Insidentibus Humido*, Part 24. as we have it from the learned *Barrow*, uses it in that Sense, because say they, it is only that which is moistned by Water, that can properly be call'd humid, and in this Sense it is that Air is humid, when fill'd with aqueous Vapours; Dryness is contrary to Humidity, and a Cloth which is said to be humid, when it is wet, is said to be dry, when the Water whereby it was wet, is evaporated.

2^{ly}. Water is hard and liquid successively, its natural State being Ice, that is, when no external Cause acts upon it, it remains firm by the Frost or any other artificial Cause, and not liquid, and again upon a moderate Degree of Heat it becomes liquid and flowing.

3^{ly}. In Water, I may add Wine &c. there is an aerial Matter that is intermixt with it, as may be perceiv'd when you set a

* Whoever will be more fully satisfied of the Nature of liquid and hard Bodies in general, and of the several Properties of Water in particular, may have Recourse to *Robault's* Physicks, with the Notes on it by our learned Dr. *Clarke* Rector of St. James's, Part 1. Chap. 22. Pag. 109. &c. Where it is very curiously handled and explain'd by those two great Men.

Vessel of Water upon the Fire; for then several Bubbles of Air form themselves at the Bottom of the Vessel, and afterwards rise up to the Top of the Water; such kind of Bubbles also are form'd in Water when it freezes, which finding no Passages through the Ice, do in its endeavour to extend itself, break the same.

4^{ly}. That all Particles of Air have a centrifugal Force which repel each other from their respective Centers; which is the Reason why Air in Water takes up more Room when in Bubbles, than when it is as it were invisibly dispers'd and dissolv'd in Water; for when those several Particles of Air are got together in the Form of a Bubble, then their centrifugal Force exert themselves so, as to make them recede farther from each other, than they would do were there Particles of Water between them, which bring the Particles of Air nearer together, in their repelling Force, than they would otherwise allow.

AND 5^{ly}. from the following Experiments it may be known that Air will insinuate itself into Water or any other Liquid; for if you boil Water for three or four Hours, and when it is cold again fill a small glass Vial full of that Water, then putting your Finger on the Vial, invert in it a Glass of Water in such a Manner that there be a Bubble of Air at the Top of the Water about as big as a hazle Nut; then you will find that in twenty four Hours the Bubble will disappear, and by trying the same Process over and over again you will find the same Effects till the Water will suck in no more.

THIS is certainly demonstrable by bottled Ale, for if you fill the Bottle but half Way up to its Neck and cork it well, the Air that remains in that Space will by Degrees insinuate itself into the Liquor, and is in a great Measure that Spirit which preserves and gives it that Briskness, with which after some Continuance it abounds, which with several Observations on Spirits of Wine &c. are sufficient Demonstrations that there are great Quantities of imperceptible Air, in Water and other Liquids, which is the Cause of a kind of Elasticity in it, because abstracted from it there is no sensible Elasticity in Water itself, any other than that it makes an Equilibrium with other Bodies by its own Weight, or by the Impulse which it thus receives from Air.

THERE is also a sixth Property in Water, which, how improperly soever it be, has taken Place in the *Cartesian* Philosophy, and that is that Viscosity which is by them suppos'd to be in it, and that every Particle of Water being in a constant Motion have a Kind of Figure proper to hook and unite themselves to those of the same

same Kind, and that they fasten to each other as soon as by that Motion they come to touch, which is the Occasion of that Friction that is against the Sides of Pipes, &c.

BUT this Viscosity may be rather (as Dr. Desaguliers in his Notes on Marriotte has it) call'd the Attraction of Cohæsion, by which the Parts of Bodies cohere strongly in Contact, but act but very little one upon another at a sensible Distance, as that of a Drop squeez'd from an Orange demonstrates; for if Cohæsion were owing to the hooking of Particles together, there must be second Hooks to hold the first, and third Hooks to hold the second, and so on *ad infinitum*, which is a very unphilosophical Supposition; and that this Cohæsion relates to Friction, or which is indeed a Term more proper for it, will be farther demonstrated in its proper Place.

FROM these Preliminaries then concerning the Etymology of Hydrostaticks, the Definition of Liquids and Fluids, and the Properties of Water, &c. let us, to sum up all, have Recourse to the Method Dr. Desaguliers has defin'd the Principles of Hydrostaticks by, in his excellent Lectures on Experimental Philosophy, in the following Manner.

1st. "A Fluid is a Body, whose Parts yield to any Force impress'd, and by yielding are easily put in Motion.

2^{dly}. "A Solid is a Body whose Parts are so connected, as not to be divided without a determinate Force; but by Solidity he does not mean that Property of Bodies whereby they resist Penetration, but the Cohærence of the Parts, by which they endeavour not to be separated; and thus as before according to Ozanam, a Fluid is a Body which is easily passed through, and whose separated Parts join again immediately; as Air, Flame, Water, Mercury, and other Liquids do: A Liquid, which is a Fluid also, continually spreads itself below the Air, till its upper Surface is level, or in a Horizontal Position, *ut antea*.

3^{dly}. "Gravity is that Force, which pushes Bodies downwards.

4^{thly}. "One Body is said to be intensely or specifically heavier than another, when it has more Weight, and the same Bulk, or as much Weight and a less Bulk.

134 *An Introduction to a General System*

“ LET A, be an Inch Square of Wood, and B, an Inch of Lead
 “ if B weighs 4 Ounces, and A but
 “ one, B will have four Times the
 “ specifick Gravity of A.

“ OR, let A be an Ounce of Wood,
 “ and B an Ounce of Lead, if A be
 “ four Times greater than B, then B
 “ will have four Times the specifick
 “ Gravity of A ; for there is a reci-
 “ procal Proportion between the Bulk,
 “ and the specifick Gravity of *Æqui-*
 “ ponderous Bodies.



See the Squares.

THE Properties of Fluids in Respect to their Gravitation, &c. have been handled in a very accurate Manner by the learned *Wallis*, *Boyle* and others, in near 20 Propositions ; all which may, I think, be reduc'd into two, and those are concerning those Bodies which press upon the upper, and those that press upon any Parallel Surface within the Fluid.

THE primary Property of heavy Fluids are these, (to use the Words of a learned Divine on this Head) that if a heavy Fluid, as A, B, C, D, (*Fig. 1. of the following Plate*) be either not press'd at all, or equally press'd from above, its upper Surface A, B, will lie Horizontal or Level. And if the said Level be disturb'd, it will by its own Gravity return to the same Level of its upper Surface ; for the lower Particles of the Fluid will not, by Reason of their Gravity, ascend upwards of themselves to raise any Part of the said Surface above the other ; (for as Dr. *Desaguliers* demonstrates Prop. 1. of his *Hydrostaticks*, the superiour Parts do press upon the inferiour by their Gravity ;) nor can those upper Particles descend, since there is no Room for them in the lower Part of the Vessel, it being taken up by those other Particles of equal Weight with themselves : And therefore if there be no Pressure at all from above, or an equal Pressure, then there is nothing to disturb or alter the Level of the upper Surface ; but if it be disturb'd, the Fluid will return to its Level, because the higher Part H, I, (*Fig. 1. Tabula seq.*) being heavier, will partly depress the Particles under it, and will partly run down into the lower Part, and that so long as any one Part of the Surface is higher than the other.

AND on this Principle (as the learned Dr. has it) are founded all Water-works and Fountains ; that according to the Height of

of their Reservatories, so high will the Water rise (*viz.*) if the Reservatory be twenty Foot, the spouted Water will rise twenty Foot, allowing for the Resistance of the Air.

To demonstrate this Principle farther. If the Fluid (*Fig. 2.* of the following Plate) be from above unequally press'd, it is obvious, that the Part thereof A, E, which is most press'd, will descend, the Particles so press'd thrusting out of their Places the other Particles, that are either not press'd at all, or less press'd; which therefore will ascend to H, I, in Proportion to the Descent I, G, of the Particles press'd A, E, namely, as the Part press'd A, E, is equal to or not less press'd, E, B, so the Ascent E, H, or B, I, will be equal to the Descent A, F, or F, G.

WHAT has been said of the upper Surface A, B, holds good of any other parallel Surface within the Fluid, as E, F, (*Fig. 3.*) namely, if it be equally press'd by the upper Part of the Fluid, and withal by any thing else swimming, either at the Top or within the Fluid, it will retain its Horizontal Situation or Level; but if it be any where press'd more than in other Parts of it, there it will sink, the Parts of it which are less press'd ascending as that descends; and from what has been hitherto said, may be inferr'd the following Propositions as so many Corollaries.

Coroll. 1. If an heavy Body E, F, H, B, (*Fig. 4.*) lying upon a Fluid A, B, be of an equal Weight with the Air that takes up an equal Space A, H, E, G, the Surface A, B, of the Fluid will retain its Level, as being every where equally press'd.

Coroll. 2. If the Body E, F, I, K, (*Fig. 5.*) be lighter than the Air which takes up the like Space, then the said Body, and the Particles of the Fluid under it, will ascend, till the Aggregate of the Body I, K, E, F, and of the Parts E, F, H, B, of the Fluid so ascending (*viz.*) I, H, B, K, be of equal Weight with the Air that takes up the like Space G, A, H, I, for then the Surface A, B, will be equally press'd every where, both in A, H, and H, B.

Coroll. 3. If the Body E, F, A, B, (*Fig. 6.*) be heavier than the Air of a like Bulk, then the Body will swim in the Fluid, descending so far into it, till the Aggregate of the Air G, E, I, K, and the Fluid I, K, A, H, (*viz.*) A, H, E, G, which take up together like Space with the said Body, be of equal Weight with the Body; for the Surface A, B, will become equally press'd, both in A, H, and H, B.

Coroll. 4. If the Body E, G, D, F, (*Fig. 7.*) be heavier not only than the Air, but also than the Water, or any other Fluid that takes

takes up the like Space H, C, G, E, then the Body will sink quite to the Bottom C, D, there being nothing to counterpoise or bear it up till it comes to the Bottom. For the Body being suppos'd to be put on the upper Surface A, B, and to lie upon the Part I, B, thereof, it being heavier than a like Bulk of Air, the Part of the Fluid I, B, D, E, will be more press'd thereby, than the other Part of the Fluid A, I, E, C, by the Air, and therefore the Particles I, B, D, E, will descend. And in like Manner when the Body is come to G, F, it being heavier also than a like Bulk A, H, G, I, of Water, it will still press the Parts of the fluid Water G, F, more than those that are under G, H, and therefore will cause the Parts under G, F, still to give Way, till it comes to the Bottom C, D, than the Water of a like Bulk, and so must sink according to the Principles of Hydrostaticks aforementioned.

IF a Fluid (*Fig. 9.*) particularly Mercury or Quicksilver, contain'd in the Tube C, D, presses on the Part C of the Surface A, B, more than the Air presses on the other Parts, C will descend and the Quicksilver run down out of the Tube, till what is left at C, I, in the Tube presses C, just as much as the other Parts are press'd by the Air. And then no more will run out of the Tube, because of the equal Pressure in all Parts of the Surface A, B: Where it is to be noted, that this Weight of the Quicksilver C, I, is equivalent to the Weight of a Column of Air extended from the Surface A, B, up to the Top of the Atmosphere, and of the same Basis or Diameter of the Tube C, D.

AND it is observable (*Fig. 10.*) that the Quicksilver will rise up just to the same Height in the oblique or sloping Tube E, G, as it does in the upright Tube D, C, although the Quicksilver E, F, in the Tube E, G, be more, and consequently heavier than the Quicksilver C, I, in C, D. The Reason whereof is this, that as much as the Quicksilver E, F, is more than the Quicksilver C, I, so much greater is the Base E, than the Base C. This being equal to the Base of the Cylinder E, K, wherein the Quicksilver E, H, will be found to be just so much as the Quicksilver E, F, by Reason of the two Tubes E, K, and E, G, being Cylinders of equal Height upon the same Bases, and therefore equal to one another: Now it is obvious that supposing the Base E, to be twice as Big as the Base C, and consequently the Quicksilver E, H, in the Tube E, K, or the Quicksilver E, F, in the Tube E, G, to be twice as much as the Quicksilver C, I, in the Tube C, D, it evidently follows that as the Quicksilver C, I, does equipon-

derate

derate to a Column of Air of the same Base C, so will the Quick-silver E, H, or E, G.

Coroll. 5. Upon the same Principles, if a Body G, H, I, K, (*Fig.* 8.) be immerg'd into the Fluid, and be of equal Weight with so much E, F, G, H, of the Fluid, as takes up the like Space, that is in short to be of the same specifick Gravity with the Fluid, then the said Body will stay where it is plac'd in the Fluid, without either rising or sinking; for the Surface E, I, being equally press'd all along, the said Body cannot rise, and the Surface F, K, being all along equally press'd, neither can the said Body sink.

BUT if one of the said Fluids be specifically lighter than the other, and consequently the Bulk G, H, I, K, be lighter than the Bulk E, F, G, H, it evidently follows that the Surface I, K, will be more press'd in F, H, than in H, K; and consequently the Body G, H, I, K, will be thrust up and rise higher and higher for the same Reason, till it comes to such a Situation, as that it is of equal Gravity with so much Air (which in this Case is suppos'd to be lighter than the Body) and so much of the Fluid as takes up an equal Space with it (as is represented in *Fig.* 6.) But lastly if the Body be of the same specifick Gravity with the Air, then it will rise to the very Top of the Fluid, as in *Fig.* 4. I shall not attempt to reduce to Practice all that might be said in the several Cases of Hydrostaticks; but from what has been already noted it is easy to account for several Occurrences that naturally offer themselves in Fluids, I mean in that Part of Hydrostaticks that is the Design of my present Undertaking; and from hence it is easy to tell why we don't feel the Weight of a Bucket, and the Water that is in it, when we draw Water, till it begins to rise out of the Water. Namely because, supposing the Bucket with the Water in it to be represented (*Fig.* 8.) by G, H, I, K, it being of the same Gravity with the like Bulk of Water E, F, G, H, the Surface F, K, will be equally press'd both in F, H, and H, K; and therefore the Bucket of Water can't descend, but is held up by the Water under it, and consequently the Weight of it is no more felt, than is a Weight which is counterpoiz'd by an equal Weight upon a Ballance: And the same holds all the while, the Bucket is drawing up, to the Surface A, B, where it and the Water in it, coming into the Air, so much specifically lighter than the Water or Wood &c. of the Bucket, the Air can't sustain it, and so must be sustain'd by him that draws up the Bucket.

HENCE also it is easy to account how the Weight of any mighty Ship is supported by Water, it being of equal Weight
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with that of so much Water as in Bulk is equal to the immers'd Part of her, or (as the learned *Boyle* and from him Dr. *Harris* in his *Lexion Technicum* observes) to that Part of her Hull which is underneath the Surface of the Sea.

ACCORDING to the same Principles also we may easily tell why one Liquor will swim upon another, or remain at Top without mixing, if it be poured on gently; as Oyl in respect of Water; and Water in respect of Quick-silver: Namely because Oyl is specifically lighter than Water, and Water than Quick-silver.

MOREOVER the Reason why a Log of Wood that has been swimming a long Time upon Water, but will sink at last, is this, (*viz.*) Because such a Piece of Wood may be of the same or greater specifick Gravity than Water, setting aside the Pores of the Wood; but by reason the Pores of Wood are full of Air, the Air which fills the said Pores and the Wood together make up one whole, lighter than an equal Bulk of Water, and therefore the Wood will not sink at first. But after some Time the Water being got into the Pores, and so the Air excluded; then the Water in the Pores, and the Wood together, make up one Whole heavier than the Water of a like Bulk, which is double the Quantity of C, I, does but equiponderate to a double Quantity of Air that is to a Column of Air, whose Basis E is the double of the Basis C.

SINCE according to the Rules of Staticks, Bodies gravitate or weigh heavier in a perpendicular, than in any oblique or sloping Situation; it may be ask'd why the Quicksilver E, H, gravitating or pressing upon the Basis E, more than does the Quicksilver E, F, (that being perpendicular to E, this Oblique) the Quicksilver does not descend lower in the Tube E, K, and higher in the Tube E, G. The Reason then is this, that as much as E, H, presses downwards more than E, F, so much does the force at E, which (arises from the Pressure of the Air on the other Parts of the Surface A, B, and) sustains the Quicksilver in each Tube, press upwards more in the upright, than in the oblique Tube; and both for the same Reason (*viz.*) because the Pressure, whether upwards or downwards, is in the Tube E, K, perpendicular, whereas in the Tube E, G, it is oblique, and therefore not so great.

Now the Force at E, which holds up the Quicksilver in the upright Tube, being as to its Effort, so much greater than the Force at E, which holds up the Quicksilver in the Oblique, as the Weight of the Quicksilver in the upright Tube, is greater than the Weight of

of the other; it follows that the said Force at E, acting upwards according to the Perpendicular E, H, is as able to sustain the Quicksilver in the upright Tube, as is the same Force acting upwards according to the oblique Line E, F, to sustain the same Quantity of Quicksilver in the oblique Tube, and therefore the Quicksilver in the upright Tube will not descend lower by running any of it, out of the said Tube, nor will the Quicksilver in the oblique Tube ascend any higher by any more running into it; but the same Quicksilver (and consequently Water itself) will keep at an equal Height in both Tubes.

AND the same will hold good as to any other Tube, (or Vessel) of any other Shape: Namely, the Height of the Quicksilver or Water, will be the same in any Vessel, as it is in a Cylinder of the same Height and Basis with the Vessel. Thus for Instance, (vide Fig. 11. of the following Plate) the Height of the Quicksilver is the same both in the round headed Tube D, E, H, F, and the sharp-headed K, L, B, as it is in the Cylinder inscrib'd in the former (*viz.*) C, I, or the Cylinder B, L, O, P, circumscrib'd about the later. For as to the round-headed Tube D, E, H, F, as much of the Quicksilver as lies without the Cylinder C, I, is sustain'd, not so much by C, as by the Parts M, I, and N, S, of the Tube's Head, which are under them, and no more of the Quicksilver is properly or directly sustain'd by C, than what lies within the Cylinder C, I, and consequently the Effect will be the same, as if the Quicksilver was put in the Cylinder C, I.

As to the sharp-headed Vessel L, B, K, and the Cylinder B, L, O, P, the Quicksilver will likewise rise as high in one as the other; for as to so much of the said Vessel, as allows of a free Ascent from the Surface A, B, the Quicksilver will there rise to its just Height C, I, for the same Reason, as it will rise to the same Height in the Cylinder B, L, O, P.

As to the other Parts of the said Vessel, where the Quicksilver is hindred by the Sides of the Vessel to rise up to the Height C, I, as much as there is wanting in the Weight of the Quicksilver, &c. To conclude this Chapter, 'tis from Experiments of this Kind it is demonstrated that a Ship (Wood being specifically lighter than Water, especially that which is salt) will float with great Safety and Pleasure on the main Ocean; but which by being over-burthen'd, and sailing into Rivers which are less salt are apt to sink; so that when I speak of Water I always mean that which is equally heavy, or in plainer Words that I may err in the right

rather than the wrong Side, I would be always understood to mean fresh Water, the specifick Gravity whereof in relation to other Bodies will be set down in some following Chapters.

IN relation to Water, that which is salt is, as has been before observ'd, heavier than that which is fresh; and *Pliny* speaks of certain Rivers, such as the Water of the Lake *Asphaltite*, and that of *Arethuse*, which runs towards *Syracuse*, wherein nothing will sink; and it must be noted also, that Metals, and heavy Solids, sink in Water, according to the Figure they have: For Gold, Silver and Copper sinks not in ordinary Water, if they be beaten out into Plates and thin Leaves; but if it be contracted into a more solid Form, it sinks forthwith to the Bottom.



B O O K. II.

C H A P. XII.

Of the Gravitation of Fluids, according to the honourable and learned Mr. Boyle.



THE Chapter going before, in which the Principles and Problems of Hydrostaticks are mathematically explain'd, being chiefly deduc'd from *Wallis* and other eminent Writers, whose Experiments on this Head are therein set down; I have added this other Chapter from the honoured and learned Mr. Boyle, in which with more Ease yet great Accuracy and Plainness he has brought to Light whatever was mathematically, and so more obscurely handled by others.

THAT admirable Gentleman (who was so great an Honour to his Country) considering that all Persons are not acquainted with, and cannot so readily digest rigid mathematical Demonstrations, reduc'd the chief of the hydrostatical Theorems into about

Plate 4

Fig 1

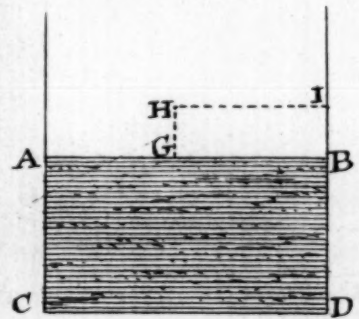


Fig 2

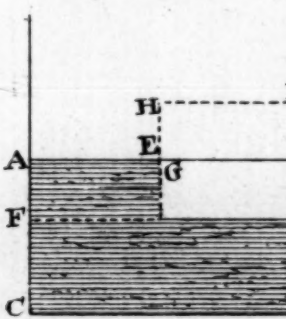


Fig 6

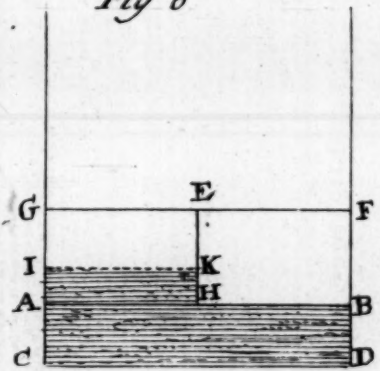
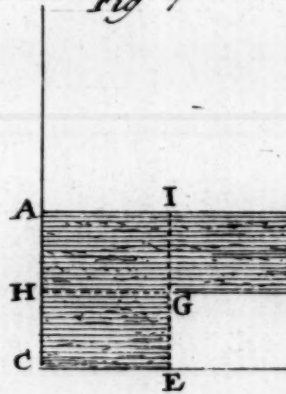


Fig 7



2

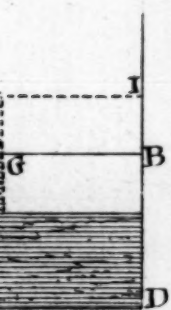


Fig 3

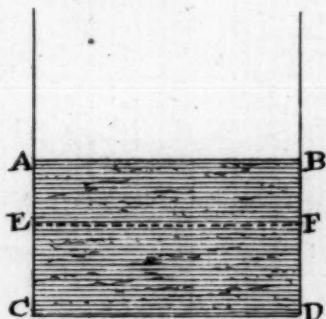


Fig 4

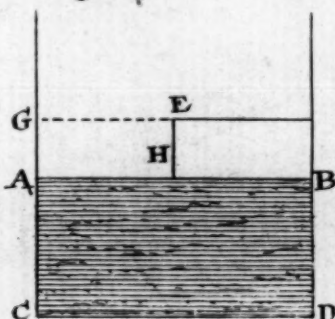


Fig 5

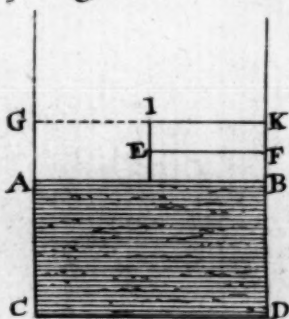
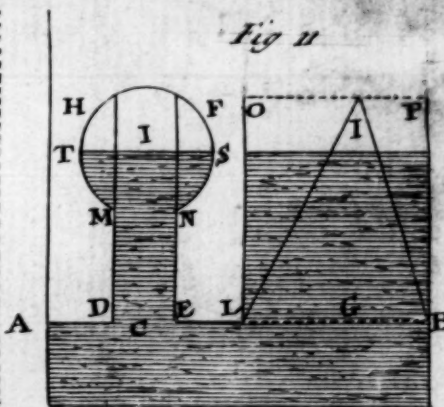


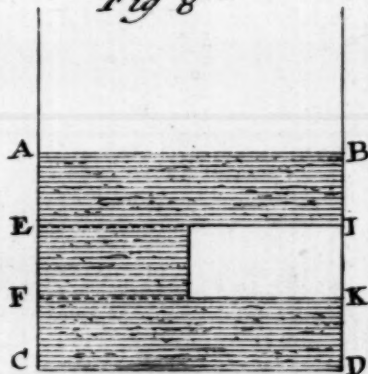
Fig 11



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Fig 8



C

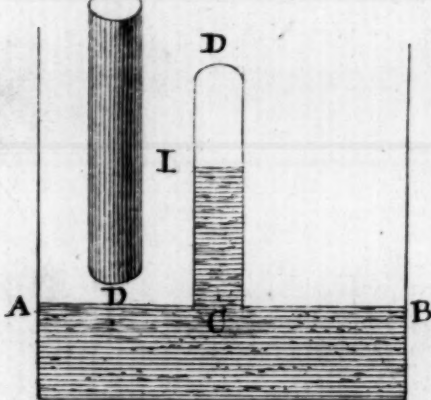
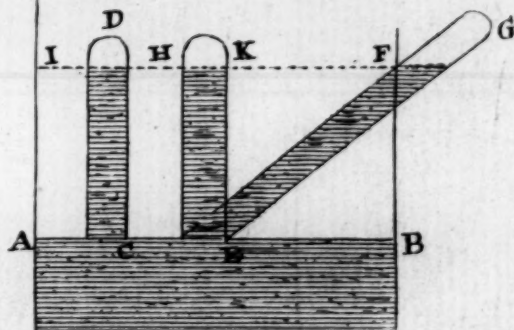


Fig 10



eleven Propositions or Paradoxes; a more full Account of which is to be found in a little Treatise of his, entituled *Paradoxa Hydrostatica*, premising in the Front of it several things proper to be known in this so curious a Subject, under the Title of *Proposulata's* or *Lemmas*.

THE first is (*vid. Pag. 7.*) that if a Pipe or Tube opened at both Ends, and plac'd perpendicularly to the Horizon, have its lower Orifice under Water, there will be an imaginary Plane parallel in all Appearance to the Superficies of the superior Water, and which shall touch that lower Orifice of the Tube.

Secondly, that each Part of this Surface or Plane will be alike press'd by the Perpendicular incumbent Water: Notwithstanding the Opinion of those who hold *that Water will not gravitate on Water, nor Air on Air*; which must be granted, since the Water being suppos'd to be an homogeneous Fluid of the same equal Parts, and of equal Gravity every where, and of equal Height above the Plane; there can be no Reason why one Part should be more press'd than another, it having the same Base, and the same Altitude, and consequently the same Quantity of Liquor pressing every where one upon another.

Thirdly, that tho' Liquor will keep its former Position, yet when there is a greater Weight laid upon any one Part more than there is upon another, then that Part is press'd downwards, or otherwise made to give Place, and slip, on one Side or the other, as is the Case when a Stone, or I may add a Piece of Lead or any other Material which is specifically heavier than Water is, sinks down in it, and tends to the Bottom; because in what Part soever the Stone or Lead descends, that Part being more press'd than the rest, gives Way to the superior Force of the Stone, and never rests till it comes to the Bottom.

AGAIN if any Part of this imaginary Surface be less press'd upon than the rest, it must by that greater Pressure, be impell'd upwards, till it have an Height equal to ballance the Pressure made on the other Parts of the Water: Which will appear highly reasonable to any attentive Considerer, and the Truth of which is thus prov'd.

SUPPOSE a small Tube open at both Ends, be plac'd perpendicularly beneath the Surface of the Water in any Vessel, (those of Glass as being transparent are the best; because the Ascent of the Liquor will be the more visible) then will the Water by the known Laws of Hydrostaticks rise in the Tube as high and a little higher than the Surface of the Water without: But if you gently
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pour Oyl of Turpentine or any other Liquor (which will not incorporate with the Water) upon that which is contain'd in the Vessel; you will see, that as the Oyl grows higher and higher on the Surface of the Water, and presses consequently more on it, so will the Water rise in the Orifice of the Tube, and descend again proportionably as the Oyl is taken off, which plainly proves that the Weight of the Oyl pressing more on the Surface of the Water without the Tube, than the bare Air can do within it, forces up the Water so high in the Tube, till the Cylinder of Water within the Tube, gravitates as much on that Part of the Water under the Orifice of the Tube, as the Air, Oyl and Water together do on all the others without it.

I SHALL not, in the short Compass I propose to allow my self in this Chapter, expatiate on all the other Parts with which the honoured and very learned Gentleman before mention'd introduces his preliminary Discourse, but come to the Practice it self.

P R O P O S I T I O N. I.

That the upper Parts of all Fluids, as Water &c. do press upon the lower.

PROVIDE a glass Jarr, such a one as is seen *Fig. 1.* in the following Plate; fill it with Water near full, as up to A, B; then take a glass Pipe or Tube open at both Ends, and dipping the lower End into Oyl of Turpentine, you may, by stopping the Top with your Finger, suspend as much of the Oyl as you please in the Tube: This done move the Tube into the Glass of Water, and thrust it down till the upper Surface of the Oyl in the Tube be near as low as the upper Surface of the Water; and when you take your Finger from the Top of the Tube, you will see the Oyl will not run out at the lower Orifice of the Tube; nay if you thrust the Tube lower down into the Water, that Liquor will rise up in the Tube and bear up the Oyl above it; but if you raise the Tube up so, as that the upper Surface of the Oyl in it be considerably higher, than that of the Water, the Oyl will drop out of the Tube, and rise up to the Top of the Water. The Reason of which is this; when the imaginary Surface G, H, on which the End Q, of the Tube B, Q, rests, is as much and no more press'd upon, by the Oyl, in the Pipe, than the other Parts of that Surface are by the Parts of the Water which are perpendicularly incumbent on them; then there is an Equilibrium be-

between the Oyl and the Water, and so the Oyl can't run out; and when you sink the Tube down as low as O, the incumbent Water gravitates more on the Surface or Plane E, F, than the Oyl in the Tube doth on the Part under it; and consequently the Water will be forc'd up into the Tube, and bear the Oyl above it, and the Water will rise so high, as that it, and the Oyl together in the Tube, N, O, do gravitate as much on the Surface E, F, as the other incumbent Parts of the external Water do: But if you raise the Tube up into the Position R, S, the Oyl in it, pressing more on the imaginary Surface I, K, than the incumbent Water does on any other Part of it, the Oyl must run out, till so much descend out of the Tube, as will bring the Weight of the Oyl, to an Equilibrium with that of the Water, which demonstrates the Truth of this Proposition. * For if the Experiment be try'd in any two other Liquids that won't mingle and incorporate with one another, it will have the same Effect, provided the Pipe be not too large.

P R O P O S I T I O N. III.

That a lighter Fluid may gravitate or press upon a heavier.

FILL a Jarr or Vessel with Oyl of Turpentine instead of Water, and then place in it a Tube of the same Dimension as the former, in which there is suspended a Column of Water in the same Manner as you did before that of Oyl; and you will find that tho' the Water be heavier, than that of the Oyl of Turpentine, yet if you don't take away your Finger, from the upper Orifice, till such Time as you have sunk the Pipe so low, as that the upper Surface of the Water in it, be a little below the Surface of the Water of the Oyl in the Glass; then I say, that on taking away your Finger you will find the Water in the Pipe will not run out: That if you sink the Tube lower, or pour more Oyl into the Vessel, the Oyl will rise up in its lower End; and that if you raise it higher, then the Water will drop or run out, and fall to the Bottom of the Vessel, which plainly shews that one Liquor which is specifically lighter than another may by its own Gravity (being when compos'd of a greater number of Parts join'd together) press upon one which is more heavy.

* To wit that contrary to what the Peripateticks have asserted, that Water does not gravitate on Water, nor Air on Air; yet here it is plain that the upper Parts of all Fluids do gravitate or press upon the lower.

144 *An Introduction to a General System*

AND agreeable to the Explication of this, as well as the foregoing Experiment, it is; that there (I mean in the first) the Superficies of the Oyl in the Glafs was always higher than the Superficies of the Water without it, the Oyl which was the lighter Liquor requiring the Height to be greater on Account of the Equilibrium; so in the present Experiment the Superficies of the Liquor in the Tube was always lighter than the Oyl which was without it; for if in the imaginary Plane E, F, (*vid. Fig. 2. Tabula seq.*) the Cylinder of Water I, G, is at rest in the Tube I, H, it will on Account of its greater Gravity press upon the Part I, and the distill'd Oyl (K, E, F, L,) which is a lighter Liquid, then it can press upon the other Parts of the same suppos'd Plane, E, F, although it should raise the Oyl to a Height greater than its own.

BUT this Proposition is confirm'd by our oft-quoted honourable and ingenious Author by another Experiment, into a long glafs Tube seal'd up at one End, and whose Bore is about half an Inch; let there be poured a Quantity of Water, and then having a small glafs Bubble about the Bigness of a Pea, with a very small and slender Stem, (as is seen in *Fig. 3. Tabula seq.* afore said) let this Bubble be so exactly poiz'd by forcing Water into it, that tho' it should not sink in a Vessel of Water at first Tryal, yet a little more Weight would make it do so.

THIS Bubble being put into the glafs Pipe will swim on the Top of the Water contain'd in it; but when Oyl of Turpentine is pour'd very gently on the Water which is in the Pipe, and till it has attain'd to a convenient Height above the Surface of the Water, it is visible that the Bubble which before swam on the Surface of the Water, will sink then down to the Bottom, and stay there, so long as the Oyl was kept upon the Water; but if either the Tube was any Way very much inclin'd, or if the Oyl by a Siphon or any other Instrument was drawn off, then the Bubble will rise to the Top again.

THE Reason of which is plainly thus, that when the Oyl is poured on, that did (tho' a lighter Fluid than Water is) by its own proper Gravity, (consider'd as a larger compounded Body) press upon the incumbent Water, and by that Means did force some of it to enter in at the little Stem of the Bubble; which by that Means being rendred more ponderous in the Whole, did sink to the Bottom; but when the direct Pressure of the Oyl upon the Water was taken off, by inclining the Tube, or remov'd by drawing off the Oyl quite, the Air which is in the Bubble before will by its own

own Elasticity (of which more will be said elsewhere) force out the newly admitted Water again, and so reduce the Bubble to its former Degree of Gravity in such a Manner as that it would rise in the Water as before.

It was found also that pouring on more Water will produce the same Effect, if by a Wire thrust down to, and then kept at the Bottom of the Tube; for tho' it would readily rise again on the Removal of the Rod or Wire, when no more Water was poured into the Tube; yet that if the Wire kept the Bubble at the Bottom till more Water was poured in, to the Height of about two or three Foot, the Bubble would then on the Removal of the Wire stay there, and not rise at all till the same Quantity of Water was taken out which was before added.

THIS I think may truly be said to illustrate and prove the first Proposition, *that the upper Parts of all Fluids do press or gravitate on those which are under*; as also this 2. (*viz.*) *that a lighter Fluid may gravitate or press upon a heavier*, which I take to be one of the noblest and most useful Theorems in Hydrostaticks; because from hence it is that Air tho' 800 Times lighter than Water is demonstrated to gravitate thereon, and raise it to a determinate Height; for tho' the Particles, of which it is compos'd, be as it were imperceptible, yet when taken altogether as a Body making up that which we call the Atmosphere, the Bulk of it is regularly ponderous, and by its Pressure effects all those things which by the precise Laws of Hydrostaticks we discover; but of this more is said in its proper Place.

PROPOSITION III.

If a Body contiguous to Water be altogether, or in Parts lower than the upper Surface of the Water, the lower Part of the Body will be press'd upwards by the Water which toucheth it beneath.

THE first experiment shews that the Oyl of Turpentine was kept in an open Tube from descending or running out of it, by the Pressure upwards of the Water in its lower Parts, and by the last Proposition it appears that Oyl (tho' a lighter Fluid than Water) could press upwards, or keep Water; a Fluid specifically heavier than Oyl is, suspended in an open Pipe.

BUT in order to estimate how much the Pressure of the Water against the lower Parts doth amount to, let it be suppos'd that

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any other Kind of Liquid which is heavier than Water, as Oyl of Cloves, Cinnamon, &c. were taken into a Tube, and then that Tube were as in the former Cases, immers'd or sunk into a Vessel of Water, and there plac'd so shallow, that the Oyl on removing of the Finger from the Top of the Tube, would drop out. The Drop G, (*vid. Fig. 4. of the Plate following*) being specifically heavier than Water would, by the 3 Postulata's just laid down, sink to the Bottom, but not so quickly as it would in the Air; and since if it were a Matter equiponderant to Water as Wood and some other things are, it would not sink at all, or but just emerge: It now sinks by no greater Degree of Gravity, than that by which it surmounts a Quantity of Water equal to its Bulk, and consequently it would lose in the Water just as much of the Weight as it would have in the Air, as so much Water as is equal to it in Bulk, if weigh'd in the Air also, would amount to; which is another physical Demonstration of these noble and useful Theorems in Hydrostaticks. To proceed,

THE Pressure of Water also against the lower Parts of any immers'd Body, is confirm'd by attending to the Reason why Oyl specifically lighter than Water doth rise out of it, and swim as it were upon it; which is this, that there is a greater Pressure or Weight on every other Part of the imaginary Surface of the Water (as suppose I, K, *Fig. 1. of the Plate following*) than there is on that on which the rising Body leans; and consequently produces an Equilibrium in the Fluid; the Parts immediately under the rising Body being press'd by the rest every Way, must continually force it upwards till it attain the upper Surface of the Water: For the immersing Body is continually press'd upon by the two Columns of Water, one bearing against its upper, and the other against its lower Parts; the Length of both which being to be accounted from the Top of the Water, that which presses on the lower Part, will be the longer by the Thickness of the ascending Body, and consequently over-balance it by the Weight of as much Water as will fill the Space that the Body takes up: Wherefore the greater Disparity there is between the specifick Gravities of Water and the emerging Body, and the larger the Particles are which emerge, the swifter they will ascend, which will be a great Assistance in the accounting for the Truth of that Problem, the Solution of which is propos'd by Writers in Hydrostaticks (*viz.*) how it comes to pass, that if any cylindrick Staff be cut into two Parts, one half whereof is doubly as long as the other, and both being detain'd under Water of an equal Depth, but being let go
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at the same Time, and suffer'd to emerge, the largest will ascend faster than the small one.

SUPPOSE one of these Bodies as O, P, *Fig. 4. (Tabula seq.)* be two Foot long, but the other Q, R, but one Foot, and that the lowermost Superficies of them both be in the same imaginary Plane parallel to the uppermost, and three Foot Distance; the Case must be thus, the longest will come first to the Top, because that the Columns of Water which press against the lower Ends of both being equal, but that Pressure shortest which presses upon the upper End of the longest Piece; it must be less press'd downwards than the other Piece is, and so by the general Pressure upwards will rise the fastest; and from hence may be probably deduc'd (as our ingenious Author Pag. 68 of his Hydrostaticks in the *Latin* Edition has it) that which is often observ'd in the Distillation of the Oyls of Anise, Clove, Gillyflowers, and a great many other aromack Vegetables in an Alembick by the help of Water, which having very minute Corpuscles, either lighter or heavier in Specie than the Liquor they are mingled with, and when the Heat is withdrawn from them, may be kept there a good while without rising to the Top or sinking to the Bottom, their Thickness being indefinitely made small, the Difference between the two Columns beforemention'd will be so too, and consequently neither of them can much over-balance one another; and from hence may be prov'd what is affirm'd by *Archimedes* and other Writers in Hydrostaticks, that any Body which is equiponderate or of equal Weight in Specie to Water, in whatsoever Place it is put, it will there remain quiet.

AND that we may carry the Matter farther, if the Drop G, *Fig. 3. (Tabula seq.)* aforesaid was any Material not heavier than Water, it would neither sink lower nor rise higher; it would follow from the same Rule, that if it was heavier in Specie than Water, the Fall or sinking would be according to its Gravity, and that it would lose that Weight in Water which it has in the open Air, which is one of the physical Reasons of that great Hydrostatical Theorem, which is so solidly and clearly demonstrated by the most learned *Stevinus* himself.

THIS ingenious Proposition of Bodies swimming is very clearly taught and prov'd by the subtle *Archimedes* and his Commentators in his two excellent Books *de Insidentibus Humido*; and from hence may be accounted the Quantity of any floating Body which is beneath the Surface of the Water, *which is always in Bulk equal to as much Water as the whole floating Body doth weigh*; for this

floating Body doth by its lower Parts press upon the subjacent Parts of the imaginary Surface of the Water X, W, (*Fig. 5. Tabula seq. prædict.*) just as much as the Columns of Water to the Altitude A, X, or B, W, do on all the other Parts; that is just as much as the Water would do if it were in the Space which the immers'd Part takes up, or as much as a Quantity of Water equal in Bulk to the immers'd Part could do.

FROM hence is clearly demonstrated that the Weight of any Ship, being the same with that of so much Water, which is in Bulk equal to the immers'd Part of her, or to the Part of her Hull which is underneath the Surface of the Sea, all which was accurately discover'd by our most noble Author, who took a broad shallow Vessel and fill'd it almost to the Top with Water, and then plac'd it in a glass Tumbler or short drinking Glass; and to make it resemble a Ship, he fitted a wooden Deck with a Mast &c. to it; and then he sunk it by ballasting it with Sand, and made it in the Language of Seamen draw as much Water as he thought fit: Then by exact Remarks he distinguish'd how much the Water which was in the containing Glass rose on the Sides of the Vessel: This done he took the Tumbler out and wip'd it clean, and then weigh'd it, and so found a Quantity of Water exactly equal to that Weight; and from hence is deduc'd an Argument in Favour of the learned *Stevinus*, who in some of his Hydrostatical Propositions deduces it as a Corollary, * *That a whole Ship and all things which belong thereto, or lie upon it press neither more nor less, on the Bottom on which they swim, than such a Mole or Column of Water, which is equal to that Part of the Ship, which was below the Superficies of the Water does.*

BUT this must be said only of Salt or Sea-water which is specifically heavier than that which is fresh, it having been observ'd by some Ancients as well as Moderns, that Ships which have return'd heavy laden home, and have drawn Water nearly up to the Deck, have when they have come into fresh Water have sunk; and this is the Reason why all good Ship-builders are so very exact in their Calculations of the Number of Tunns, every Vessel is fit to carry.

* *Navis tota, omniaque, quæ ad eam pertinent, vel ei incumbent, non magis nec minus premunt Fundum, cui supernatant, quam tanta Moles aquæ, quanta æqualis est isti Navis parti quæ est infra aquæ Superficiem (vid. Scholium in Boyle's Paradoxa Hydrostatica) Pag. 78. of the Latin Edition.*

PROPOSITION IV.

That in the Ascension of Water in Pumps &c. there is nothing requir'd to the raising of Water but the just Weight of some other external Fluid.

THIS Ascent of Water in Pumps having been already from the Propositions of the learned *Wallis* and others so fully explain'd, I shall be the shorter in my Account of it in this Place; because it is demonstrable by this one easy Experiment of our learned Author.

TAKE a single glass Tube, such as is us'd in the first Experiment, about an Inch high, deeply ting'd with the Infusion of Brazil-wood, Cochineel, &c. that the Experiment may be more plain, (then stopping the upper End with your Finger) place it in a Glass fill'd with the same tinged Liquor, and that so low, that the upper Surface of the Liquor in the Tube be at least an Inch below that of the Liquor of the Vessel; then pour on Oyl of Turpentine for about 3 or 4 Inches Height above the Water in the Vessel, and you will see on the Removal of your Finger from the Top of the Tube, that the tinged Water will be rais'd or impell'd upwards near as high as the Surface of the Oyl.

Now in this Experiment there is no Colour or Reason to be assign'd to the *ancient pretended Abhorrence of a Vacuum which was suppos'd to be in Nature*, as the Cause of the Ascent of this Water; for the Tube is full of Air, and the external Air hath a free Ingress into it: But the plain Reason is this, that there being a greater Pressure made by the Oyl and Water together on the imaginary Plane, which passes by the lower Orifice of the Tube without the Tube, rather than within it, (for within there is a Pressure only of an Inch of Water, and of a Column of Air) the Parts of the Water at the Bottom of the Pipe must be thrust upwards into it, till it rise so high as to gain in Equilibrium with the rest; and this demonstrates the Rise of Water in Pumps where the external Air pressing every where on the Surface of the Water in the Well, but not on that which is within the Pump, the Force of which is lost by the Closeness as well as the passing and repassing of the Sucker; which is therefore with soft Leather made stanch on Purpose; on the raising of the Sucker the Water must follow if the Pump be good; because the Weight of the whole Atmosphere presses upon the Surface of the Water in the Well,
(but

(but not at all within the Body of the Pump) and so raises or forces it up into the Cavity thereof; and that this Pressure of Air is the Cause of the Water's Ascent, is more than probable; because no Pump can ever raise Water above 33 or 34 Foot (as is elsewhere observ'd) which is found to be exactly agreeable to the different Gravity of Air and Water, allowing for the great Height of the Atmosphere.

I might in this Place have expatiated on the different Heights, Liquids of different Weights, as Oyls, Mercury, Wine and others will rise, which is indeed no other than according to the specifick Gravities of each, but that will more properly fall in, in another Place.

P R O P O S I T I O N V.

That the Pressure of any external Fluid is able to keep up any heterogeneous Liquor of different Kinds, suspended at the same Height in several Tubes or Pipes, tho' they be of different Diameters.

TAKE a wide-mouth'd Glass (such as *Fig. 7.* in the Plate following) of a convenient Depth, and put into it a sufficient Quantity of Water well ting'd with Brazil or any colour'd Water, then fit to it a Cover of Cork through which bore with a red hot taper Iron several round Holes to admit Tubes of different Bigness or Sizes.

LET these Tubes stand nearly upright in the Vessel, and each of their lower Orifices below the Surface of the Water; then at a Hole purposely left for it, pour in gently by a glass Tunnel a good Quantity of the Oyl of Turpentine, and you will plainly see the ting'd Water rise equally (i. e. to equal Height) in all the Tubes, tho' of very different Bores and Sizes.

LET E, F, (*Fig. 7. prædict.*) represent the Surface of the Water in the Vessel, when the Oyl (being not of a Nature to mix and incorporate with it) will swim at Top, and with an equal Gravity press upon all Parts of the Surface of the Water; and consequently will raise or press up the Water in the Tubes, till it come near to the same Height in them, as the Oyl is at in the Glass, to bring the Liquors to a Ballance. But there can be no Reason why the Water (being of an equal specifick Gravity) should rise higher in one Tube than another; because the Oyl presses uniformly and equally on all Parts of the Surface of the Water; and consequently can raise the Water no higher in the same Tube, than in the large

large one, for if it should do so, the Water in the small Tube must be of a much greater Length than the corresponding Column of Oyl, whose Diameter is equal to the Orifice of that Tube; and which keeping it up by equiponderating with it, does require: But then it must be heavier than it, and so would sink down and drive the subjacent Water away to make Room for its Descent: Wherefore no Cylinder of Water in any Tube can be higher than an equal Cylinder of Oyl that bears or buoys it up; and this being the Case with them all, they must be of the same Height; that is, the Water will rise in one Tube as well as another, be their Bores never so different, and the Reason is, because one is born up by a corresponding Column or Cylinder of Oyl, whose Diameter is the same with the Tube.

NEVERTHELESS this does not contradict the Rise of Liquids in Capillary Tubes, when press'd by Fluids of different Gravities, as before set down on the Original and Rise of Springs; nor yet the Spouting of Liquids in open Air, which always rises the highest in Proportion, as they are nearer or farther off from the Center of Gravity; but of this no more at present.

PROPOSITION. VI.

IF a Body be plac'd under Water, with its uppermost Surface parallel to the Horizon, the direct Pressure which it sustains is no more than that of a Column of Water, having the horizontal Superficies of the Body for its Basis, and the perpendicular Depth of the Water for its Height. And if the Water which leans on the Body be contain'd in Pipes open at both Ends, the Pressure of the Water is to be accounted for by the Weight of a Pillar of Water, whose Basis is equal to the lower Orifice of the Pipe, and its Height equal to a Perpendicular reaching from thence to the Top of the Water, though the Pipe be much inclin'd; nay, or tho' it be never so irregularly shaped and much broader in some Places than at the Bottom.

THE learned *Stevinus* (as we have it from Mr. *Boyle*, p. 99. of his *Paradoxa Hydrostatica*) in the 10th Proposition of his Elements of Hydrostaticks, after he had propos'd the former Part of this Paradox, adjoins a Demonstration to it in the following Words:

IT being first suppos'd that A, B, C, D, (*Fig. 5.* of the following Plate) is a solid rectangle Figure, whose Base E, F, is par-

parallel to the Horizon, and whose Altitude G, E, is a Perpendicular let down from the supreme Superficies of the Water to the Bottom.

IF the Bottom E, F, should be loaded with a greater Weight than is the Weight of the Water G, H, that Superpondium or over Ballance must necessarily arise from the Contiguous Water; there it is possible it may rise from the Water A, G, E, D, and H, B, C, F, which being granted, the Bottom D, E, will in like Manner rather have the incumbent Weight on it self, on Account of the Neighbouring Water, than the Weight of the Water A, G, E, D; and when the Reason in all these three Cases is the same, the Base F, C, ought to sustain a greater Weight, than the Base of the Water H, B, C, F; wherefore the whole Bottom or Base D, C, will have a greater Weight incumbent on it, than that of the whole Water A, B, C, D, which nevertheless (the Body A, B, C, D, being rectangular) was absurd; and by the same Method of Reasoning shall be prov'd, that the Base F, C, does not sustain less Weight than the Base of the Water G, H, E, F; and therefore as it does not sustain neither more nor less Weight, it is necessary it should sustain so much of the precise Weight, as the Column of Water G, H, F, E, amounts to.

THIS Method of *Stevinus*, the learned *Boyle* found to be not exactly agreeable to Truth, and therefore he invented several of his own; for the first of which take the following Directions.

PREPARE a slender glass Pipe of an equal Bore, turn'd up one End like that in Figure 7 Plate the following; dip this Tube open as it is at both Ends into Oyl of Turpentine, till the Liquor be risen up to two or three Inches in the longer Leg, whose upper Orifice then stop with your Finger; and then remove your Tube into a Glass of Water, and hold it so that the Surface of the Oyl in the longer Leg of the Pipe be but a very little higher than that of the Water; and then if you take away your Finger which stoppt the Pipe, you will see the Oyl still keep its Station, and not at all, at least very little, rise or fall; but if you sink the Tube lower, the Oyl will rise, and if you rise the Tube higher, the Oyl will run out at the lower End; from whence it appears, that of all the Water in the Glass no more pressed on the Orifice of the Pipe, than a Cylinder equal to it in Diameter; and in Length equal to the Distance which is between the Orifice of the Pipe and the Top of the Water, (as may be also easily found, if you make a Siphon whose shortest Leg shall be long enough to counter-

counterpoize such a Cylinder of Water as will counterpoize the Oyl in the longer) for when by raising up the Pipe, you shorten that Cylinder, the Oyl will run out: As when by sinking it lower, and so lengthening the Cylinder of Water, the Oyl will be forc'd up higher into the longer Tube.

By Experience also it will be found, that this Proposition will hold good, whatever the Figure of the shorter Tube be, whether opening broad like a Tunnel by Degrees, or whether it have a sphærical or otherwise figur'd Cavity, of considerable Dimensions in the middle of it.

FOR the honourable and learned Author, whom we can never mention but with Admiration, on account of his many excellent Qualifications, found by providing a Siphon of that (*Fig. 8. Tabula seq.*) and pouring in Mercury, till it reach'd up to the Bottom of the globular Part of the shorter Leg, and to an equal Height in the longer Leg of the Siphon, that if he poured in Water at the Top of the longer Leg, it would drive up the Mercury into the Ball of the shorter, and more than half its Cavity (which it would have filled quite had the other Leg been long enough) and that this Ball in the middle of the short Leg, tho' it contain'd a very great Weight of that fluid Mercury, did no more hinder it from rising to its due Height, according to the different specifick Gravity of those two Liquors, Water and Mercury, than if the shorter Leg had every where been of the same Dimensions with its upper Orifice D; for the great Quantity of Mercury which was forc'd up into the Ball, was there in a good Measure supported by the Bottoms and Sides of it, and no more gravitated on C, than what lay perpendicularly over it, between B and C.

AND farther he took (that he might the better make out the Truth of this Proposition or Paradox) three glass Pipes L, O, G, of such irregular Shapes as is seen *Fig. 10. (Tabula seq.)* and these by Holes made on Purpose for them in a Covert of Cork, he placed obliquely within a glass Vessel fill'd with Water up to A B, and then by the Help of the Tunnel I, he gently poured in Oyl of Turpentine, till its upper Surface reach'd to F E; which Oyl he found did by its Pressure, on the Surface of the Water, raise it up to an equal Height, in all the three Pipes.

AND this which follows, very well agrees with that which goes before. Let there be procur'd three Tubes as is seen in *Fig. 11. Tab. seq.* of an irregular Figure; the Angles of one of which shall be acute as is N°. (1.) another of a Helix or spiral Line, Shape such as is N°. (2.) and the other of an irregular curve Figure, as

154 *An Introduction to a General System*

is N^o. (3.) some Parts whereof are circular, others direct, &c. and let them be fill'd with Oyl of Turpentine, which should be press'd down to a convenient Depth under Water, and there stop't up (as has been often taught) we have found that according to this Proposition, the Superficies of the Oyl in the Tube was higher than the Water which was without; the specifick Gravity of one being more than the specifick Gravity of the other: But what was remarkable in this, and the other Experiment was, that tho' the Bottoms of the Tubes were irregular, one broader, the other longer, one strait and the other circular; yet the Oyl ascended to its due Height, according to the Pressure it receiv'd from the Atmosphere.

THE most learned *Stevinus* (as our noble Author in his *Scholium* on this Paradox, Pag. 113. has it) subjoins some Confectaries, the Truth of which were more doubtful than his Theorems; on which Account Mr. *Boyle* devis'd another Experiment, to confirm the Truth of what he had before asserted.

HE order'd a Tin or latten Vessel to be made in the Shape of that (*Fig. 12. Tabula seq.*) which had a loose Bottom C, D, made of a flat Piece of Wood cover'd with a soft Piece of Bladder, and greas'd on the lower Sides near the Edges, that so leaning on the Rim of Wood G, H, contiguous every where, to the Inside of the Latten, it might easily be lifted off from it, and yet lie so close upon it at other Times, that the Water should not get between them; to the middle of the loose Bottom was also fastned a long String, that came up through the Body of the Pipe A, B.

THE Instrument thus fitted, there was Water poured in at A, which press'd against the false Bottom C, D, and kept it so tight down that no Water ran out. When the Vessel and Pipe were both fill'd with Water, the upper End of the String K, I, was fastned to the Beam of a good Pair of Scales, and then as much Weight was put into the opposite Scale, as did lift up the false Bottom C, D, from the Rim G, H, and so let out the Water; and this Weight he found to be considerably more than what would have serv'd to have lifted up as much Water as that Vessel did contain, had it been in an open one of the common Shape: But he neither sets down the Measure of the Vessel, the Height of the Tube, nor the Weight which was requir'd to raise the Bottom; but says, that *Wallis* himself calls in Question the Truth of the Paradox of *Stevinus*, which is more fully explain'd by *Monsieur Varignon* in the *Memoirs, Mathematiques & de Physique* for the Year 1692. Pag. 12.

PROPOSITION VII.

That a Body immers'd in a Fluid, sustains a lateral Pressure from the Fluid, which also encreaseth as the Body is plac'd deeper beneath the Surface of the Fluid.

ALTHO' says our noble Author, I am not to wonder that this Proposition should seem a very great Paradox to most Readers, yet I hope nevertheless, that I can evince and make plain the Truth of it, by a very great Number of Methods; especially one which is very simple and easy, and which here follows.

TAKE a slender glass Tube, and let it be bent so near the Bottom (*vid. Fig. 13. Tabula sequente*) as that the lower Part F, G, may very nearly make a right Angle with the other Part E, F: Dip this Pipe or Siphon into Oyl of Turpentine, and take up about three or four Inches of it in the Pipe, which you may keep there by applying your Finger to the upper Orifice.

THIS done move the Siphon into a Glass of Water and place it so there, that the longer Leg may stand perpendicularly to its Surface, and that the other lower Leg may be so far below the Surface of the Water, as that the upper Surface of the Oyl in the longer Leg, be but a little higher, than that of the Water in the Glass; for then if you remove your Finger from the Top, the Oyl in the Tube will very little if at all change its Station; which shews plainly that there is a lateral Pressure, against the Oyl at the lower Orifice G, which hinders its running out, tho' press'd by the Cylinder of Oyl contain'd in the perpendicular Leg; and if you raise the Pipe up higher (keeping it still in its perpendicular Posture) the Oyl will drop out; so if you sink it lower the Water will get in at G, and force the Oyl all out, of that Leg G, F, and raise it proportionably in the perpendicular one E, F; nay if you thrust it low enough, the Water will rise up into the longer Leg and bear the Oyl above it; which last Circumstance proves that the Water has a lateral Pressure against itself, as great as the perpendicular one from above, since that only can force the Water upon it to the perpendicular, and this is a plain Demonstration of the Gravitation or lateral Pressure of several Fluids one upon another, or of any one of them upon itself. To proceed,

IF also keeping the Tube at the same Depth you turn the horizontal Leg here and there, or place its Orifice G, in any Part of the imaginary Plane F, G, the Oyl will keep its former Station

156 *An Introduction to a General System*

in the Tube, and neither rise nor sink; which shews that this lateral Pressure is equal, and uniform, in all Places or Parts of a Vessel of Water, at the same Distance from its Surface; and I may add, the greater the Distance the Bottom is, from the Surface, by so much greater is the Pressure, which will more fully be demonstrated when we come to speak of spouting Liquids. And to go on,

THE Truth of this Paradox or Proposition is more amply illustrated by the following Experiment.

TAKE a small bubble Glass X, of the shape of that (*Fig. 14, Tabula sequente*) with a very slender Neck, and so well poiz'd as that it will just float in the Water and no more, (which being provided) was put into a wide-mouth'd glass Vessel, near fill'd with Water, and there left to float, on the Surface of that Liquor; then a Cover or Stopple of Cork, was well fitted to the Mouth of the Glass, and was thrust hard into it, after which there was a Hole burnt with a hot Iron, run through the middle of the Cork, into which was put a long slender glass Pipe, reaching a good Way into the Glass, and standing perpendicular to the Surface of the Cork.

ALSO in another Part of the Stopple, was another Hole burnt, and into that was fitted another glass Tube which lay sloping, but yet reach'd a pretty Way down below the Cork; the upper Orifice of this sloping Tube was well stop't with Cement, and in the same Manner were also all the Junctures between the Cork and the Glass, and between the Tubes and the Cork, carefully stop't.

THIS being all done, the Vessel was inclin'd several Ways, so that the Bubble X, might get as far as it could from the Pipe; and the more Water being poured in at the upper Orifice, of the open Pipe E, F, till it reach'd to a good Height, as suppose to K, in the said Tube, the Bubble X would presently sink to the Bottom of the Vessel, and there continue as long as the Water was continued at the same Height, in the Tube E, F; now this proves that the Pressure of the Matter, contain'd in the Tube E, F, doth not only affect the Parts of the Water immediately subjacent thereto, but also those which are more remote from it; nay and above it, since it could force the Water into the Bubble X, and so make it sink, tho' it lay not near the Orifice F, of the open Tube.

PROPOSITION. VIII.

*That Water may be made to depress a Body lighter than itself,
as well as to buoy it up.*

As wonderful as this Proposition may seem to those who are prepossess'd with Notions concerning Gravity and Levity, there is not wherewithal that those can wonder at who have experienc'd what has been already deliver'd on this Head; for when the superior Parts of Fluids, gravitate on those which are under them, and on other Bodies which lie again under them, and when any Body is unequally press'd by others, heavier or lighter than themselves, it necessarily follows that it must be drove from that Place where it is most press'd, into that which is least; if any Portion of Oyl in this Operation is so expos'd to Water, that Water may press its superior Superficies.

TAKE a slender glass Siphon E, F, G, H, (*Fig. 15. Tabula seq.*) whose shorter Leg G, H, shall be about 3 or 4 Inches long, and turn'd up as near as can be parallel to the longer E, F, which being dipt in Oyl of Turpentine till the Oyl has fill'd the shorter Leg, and rose to an equal Height in the longer.

THEN the Orifice E, being stop't with the Finger, the Pipe may be mov'd in a Glass of fair Water, till the Surface of the Liquor be about half an Inch above the Surface of the Oyl, in the Siphon; and then the Finger being remov'd from the Top, the Oyl in the shorter Leg, will be immediately driven down (according to our noble Author's Experiment) about an Inch, and as the Tube sinks lower, much more, till at last the Oyl shall be driven out of that Leg quite, and the Water following shall support the Oyl in the longer Leg, raising it also in the same Proportion; the Reason of which is plain from what has been said before.

OUR noble and ingenious Author found also that when he us'd the Siphon hereunto annex'd (as *vid. Fig. 16. Tabula seq.*) that the Water would first press the Oyl horizontally from L, to M, then downwards from M, to N, and at last (by sinking the Tube still lower) upwards from N, to P; from whence it follows, that Water presses against any Body plac'd in it all Manner of Ways, and that proportionably to the Depth of the Body in it.

P R O-

P R O P O S I T I O N IX.

That notwithstanding whatsoever has been said of positive Levity, a Parcel of Oyl lighter than Water, may be so detain'd in Water that it can't ascend in it.

THAT I may shew the more clearly (says our noble Author) those things which I have to say concerning this Paradox or Proposition, and to produce those Considerations which are necessary to explain what is here asserted; this Proposition is set down.

AND in this Case it will be useful to consider how it comes to pass, that any Body that is specifically lighter than Water, and which is collected together in the Bottom, below the Superficies of the Liquor, should rather emerge or rise to the Top, than descend to the Bottom of it, unless we should make use of the foregoing Problem in the Explication of the third Paradox; but because it is more proper to apply to our present Purpose, what is there deliver'd, I shall immediately subjoin the Reason (tho' it does not seem possible) why any Part or Portion of Oyl, tho' it be lighter than Water, should be detain'd against its own Inclination, that it should not emerge to the Top; which is because the Superficies of the Vessel being (physically speaking) full of stagnate Water, the horizontal Water, which presses the inferior Part of the immers'd Body, must be necessarily deeper than that which presses the superior.

THAT this may be reduc'd to Practice let the following Method be us'd, take only a small glass Tube, and immerge it an Inch or two under Water; stop the Orifice with the Pulp of your Finger, and then a Column of Water, of an Inch or two in Length, will remain suspended in the Tube; keep it so, and next of all dip the same Tube into a Vessel of Oyl of Turpentine, and removing your Finger, as much Oyl of Turpentine, as you please will arise into the Tube; which by putting on your Finger to the upper Orifice may be there suspended, as the Water was before; keep it so, and then immerge the Tube in a Glass of Water three or four Inches beneath its Surface, and you will find on the Removal of your Finger, that the Water will rise up into the Tube, and keep the Parcel of Oyl suspended between two little Columns of Water.

THE Reason of which has already been set down in many Instances, but may be more plainly discover'd in the annex'd Table *Fig.*

7. where P, Q, is the Water lately put into the Glafs; Q, R, is Oyl, and R, S, Water, which was firſt of all ſuck'd into the Tube; for in this Station all theſe three Liquors altogether and equally gravitate upon the Part P, and the incumbent Water only on the other Parts of the imaginary Surface G, H: Neither does the Oyl R, Q, aſcend, becauſe when the ſpreading of the Water R, S, is ſtopt by the Sides of the Tube. A, D, is higher than the reſt of the Water; by which Means the incumbent Water is brought thither, ſo that the ſuperiour Oily Part R, of the Cylinder aforeſaid, preſſes equally, and the Water endeavours again to impel the lower Part of the ſame Cylinder of Oyl Q.

P R O P O S I T I O N X.

That the Cause of the Aſcenſion of Water in Siphons, and its Transition thro' them is explicable, without having Recourſe to Nature's Abhorrence of a Vacuum.

WHEN many Philoſophers and Mathematicians amongſt the Ancients, who were not well acquainted with this Propoſition, had any Difficulty to reſolve, they had an immediate Recourſe to the *Fuga Vacui*, that ſo they might explain the Cauſe of the Transition of Liquors thro' Siphons; and thoſe Moderns alſo, which admit of a limited Vacuum (which to me ſeems certain, as our learned and noble Author has it, *Pag.* 141. of the *Latin* Edition,) they have left the Phænomenon unexplain'd, or have endeavour'd to explain it by litigious Notions, ſo that the Curious are (as he believes) much indebted to the moſt learned *Pafchal*, who has ingeniouſly undertook to ſolve the ſame.

THIS Problem is not really ſo difficult, as that we muſt have Recourſe to the *Fuga Vacui* ſo much heretofore talk'd off, for that in Truth the Explication of the Motion of Water in Siphons, Syringes, and Pumps, ſeems very conſonant to the Principles of Hydroſtaticks.

To proceed to Experience, provide a pretty large cylindrical Glaſs Tube, of about 18 Inches or two Foot long, as A, B, C, D, (*Vide Fig. 18. Tub. Seq.*) provide alſo a Siphon of two Legs, K F, K G; provide alſo a Siphon K F, K G, with a hollow Pipe, as K E, opening into or communicating with them, to each of theſe two Legs of the Siphon (one of which muſt be longer than the other) tie with a String a Tube of Glaſs I, H, ſeal'd at the Bottom, pour therein Water at E, and let it run out at I, and H, till

160 *An Introduction to a General System*

till it hath fill'd the Tubes hanging at the Ends of the Legs of the Siphon so far, that the End of each Leg be a little beneath the Surface of the Water.

THIS being done, and the Instrument and Pipe fastned in its true erect Position, if you fill the Vessel A, B, C, D, with Oyl of Turpentine, till it reach higher than the Siphon K, stopping in the mean Time the upper Orifice of the Pipe E K, with your Finger, you will find the Oyl to press so on the Water in the Tubes I and H, as to force it up into the Legs of the Siphon so high as K; and that in the removing of your Finger from the Top E, the Water will begin to run out of the upper Tube I, into the lower one H, as in or thro' a common Crane or Siphon.

Now it is apparent as Light it self, in this so well contriv'd an Experiment, that the Water runs thro' the Legs of the Siphon, tho' the Air coming down by E K, hath a free Communication with them both: So that here no *Fuga Vacui* can be pretended, as the Cause of the Waters running; but that 'tis plainly occasion'd by the Pressure of the lighter Fluid, *viz.* the Oyl of Turpentine on the Surface of the Water in the Tube I, till it force it up into the empty Leg of the inserted Siphon as high as K, and then it descends down into the lower Vessel of Tube H, thro' the larger Leg of the Siphon.

THE Oyl indeed will gravitate on the Surface of the Water in both the Tubes I and H, and there being a longer Column of Oyl over H, than there is over I, by about an Inch in Length, the Pressure will be greater on the Surface of the Water in H, by the Weight of an Inch of Oyl of Turpentine; but then it must be consider'd, that the Column of Water which descends in the Leg G, though resisted in its Motion by the Weight of an Inch of Oyl, more than the Water which tends downwards in the Leg F, is yet longer by an Inch, than the other Column of Water in the shorter Leg F, and an Inch of Water of the same Dimensions, being heavier than an Inch of Oyl, the Tendency or Motion of the Water must be from F, towards G; and not from G, towards F; and consequently the Crane or Siphon will work that Way.

“ FROM hence, (says an industrious Author, Dr. *Harris*) 'tis plain
 “ that when once a Crane or Siphon by Suction or otherwise, is
 “ fill'd with the Liquor it is to decant; if the Legs of it be not
 “ above 33 or 34 Foot long, one of them being longer than an-
 “ other, the Liquor must continue to run thro' it as long as there
 “ is any to rise in it, or that the Siphon hold stanch; but then,
 “ if never so little a Hole be made in the Crane or Siphon, or
 “ any

“ any Leak be there, the Water can no longer run, because the
 “ Air now comes to press on the Water within the Siphon, as
 “ well as on that without it, and consequently must hinder its
 “ Course of Running.”

THE same will, (with that industrious Gentleman's Leave) happen in any common Crane or Pump, where the Air will (by its Elasticity) be continually intruding itself in, at the least Intermission of the Water's running; except there is a Syringe continually at work to draw off all such intruding Air, which will still be endeavouring to destroy the Ballance in the Ingress of the Water into and Progress through the Pipe, as it is seen in decanting Wine and other Liquors where the Crane is not above a Foot high; and if it happens to be so in small Cases, what may we not expect when we are to raise and decant Water 32, 33, or 34, or more? But of this more hereafter.

P R O P O S I T I O N XI.

That a solid Body as ponderous as any known, tho' in the Surface of the Water, will sink by its own Weight; yet if it is plac'd in a greater Depth than that of its own Thickness, it will not sink, if its Descent be not assisted by the Weight of the incumbent Water.

OUR learned and noble Author is very sure this Paradox or Proposition was never before propos'd by any Body, and therefore it was not likely to appear true to those to whom he had produc'd it (the Mathematicians themselves not excepted); and that he could scarce hope that that illustrious Society, of which he was a Member, should readily and universally agree to it, unless induc'd thereto by Experience.

THAT we who are his Followers may proceed therefore in a regular Method, he has directed to fill a glass Vessel of about two or three Foot in Length (with a large Tube seal'd at the End) with Water as is seen (*Fig. 19. Tab. seq.*) If then a little Cylinder or Cube of solid Brass, as E, be any where plac'd, either at the Surface, in the Middle, or towards the Bottom of the Vessel, still it must sink to the Bottom; because the compound Column of Water and Brass together (Brass being almost nine Times as heavy as common Water is) will gravitate or press more than any Column of Water only, of the same Length and Diameter; and consequently the Brass will displace the Water under it, and sink lower and lower
 Y till

till it comes to the Bottom, and this is the Case of a Stone or any other heavy Body; but yet if you suppose this Piece of Brass plac'd on the imaginary Surface L, M, above nine Times its Depth under Water, and that it were possible to keep off the Pressure of the Water perpendicularly incumbent upon it; it is not reasonable to suppose that the Brass would sink at all, but be supported and buoy'd up there; for the Brass can in this Case charge the Water under it at F, with no more than just its own proper and absolute Weight; whereas all the other Parts of the Surface L, M, are charg'd or press'd upon by Columns of Water, which supposing them to be of the same Diameter with the Piece of Brass, (or singly heavier than the Brass, because they are above nine Times as long as the Brass is thick) and are therefore pressing or gravitating more on L, M, than the Brass doth, must of Course keep the Brass suspended which cannot sink, because it can't remove a Weight of Water heavier than it self: And from the same Principles 'tis plain from Reason, that if the Brass be plac'd yet lower, and the Pressure of the incumbent Water be (as before) taken off, instead of sinking it must needs rise, and be lifted up by Force; and this is the Reason that Bodies of different Gravities swim either higher or lower if gently immerg'd in Water according to their Thickness and specific Gravities: And this also must be the Case of a Piece of Gold (the heaviest of all Metals) if it were plac'd in these Circumstances, in a Vessel full of Water where the perpendicularly incumbent Pressure was kept off, and the Gold nineteen Times its own Thickness in the Liquor.

FROM hence I say, (says our noble Author) if any Body or Piece of Brass be plac'd deep enough below the Surface of the Water, and so defended that no incumbent Water can press it; it will be sustain'd by the subjacent Water, and this is what shall be made out farther in the following Experiment.

LET there be a Piece or Body of Brass E, F, having a Cover or brass Valve well cemented, in which let there be well turn'd and fitted a Piece of solid Brass as E, F, abovemention'd; let a deep glass Vessel be provided in the Shape of *Fig. 20*, in the following Plate, which Vessel let be fill'd with Water near to the Top, then at the Bottom thereof let there be a glass Tube open at both Ends, into which the brass Valve abovemention'd was fastned, which tho' it would stop the Valve exactly, would yet easily fall out, if not suspended or supported by any thing: To the upper Side of the brass Piece E, F, let there be a Button fastned, whereby it may

may (by Means of a String coming up through the Pipe P, O,) be drawn close up, so as to stop the Valve.

ALL things being thus fitted, if you sink the Tube with its Valve and brass Stopple fast in, till the Brass be about nine Times its Thickness beneath the Surface of the Water in the glass Vessel? You will find tho' you loosen the String, that the brass Stopple will not fall out; because the Valve being close, and the Sides of the glass Tube not capable of being permeated by the Water, there can no more of that Liquor press upon the brass Stopple perpendicularly; but whatever Pressure it sustains is from the Tendency of the Water upwards, which must needs serve to support it, since that is greater than the Weight of the Brass. But if you raise the Tube up towards the Top of the Water, the brass Weight there over-ballancing the Pressure of the Water upwards, it will soon, if not held by the String, slip out of the Valve and fall down, and the Water will immediately rise in the Tube.

BUT if instead of raising the Tube up towards the Surface of the Water X, Y, you would sink it down much deeper towards the Bottom; you will find that this brass Stopple which will fall out readily into the former Station, will now support a considerable Weight (as L,) fastned to it by a Bottom made on the under Surface of it; but that on the raising of the Tube upwards, this additional Weight will make the Stopple drop out much sooner than before: As suppose when the Tube is rais'd only to the Height of three or four Inches &c. which Experiment does abundantly confirm the Truth of this Paradox or Proposition; and no doubt had the Stopple been made of any other Metal or Material more ponderous than Brass (suppose Gold) and that the Tube had been let down into the Vessel, till that Gold or other Metal had been nineteen Times its Thickness (or what Thickness soever else its specifick Gravity requir'd) even that ponderous Metal (let it have been what it would) would have there remain'd without sinking.

FROM whence (at one View) may be seen that which happens when two plain and polish'd Pieces of Marble are join'd together, where we shall find it impossible to separate them without great Strength; neither is there Occasion to have recourse to the *Fuga Vacui* for the Explanation of Cohæsion; for whilst those Pieces are encompass'd with the ambient Air, which is a Fluid not destitute of Gravity, and stretch'd out I know not to how great a Height above the Marbles, they can't possibly separate; for then it must needs keep the Stone pendulous or buoy'd up, till such Time as the Air insinuates itself between the Stones, or that a

Weight be affix'd to the lower Stone which exceeds the Weight of a Pillar of Air, whose Diameter is that of the Marble, and its Height reaching to the Top of the Atmosphere: And that this is the Reason of their Cohæſion is plain, becauſe when they are thus ſuſpended, and do adhere to each other in the Receiver of the Air-pump, on a very few Pumpings of the Air out of the Receiver they will immediately diſjoin and fall aſunder, as ſeveral learned Men have experienc'd; and it may be prov'd that there is nothing elſe but this Preſſure of Water which I have juſt now explain'd, which cauſes this Cohæſion of the Parts of the Valve; for if it be elevated by Degrees towards the Superficies of the Water, you will ſoon find the Piece of Braſs E, F, to be drawn downwards from the Stone, which will hang to it, juſt as you perceive of Water creeping between the Parts of the Valve and aſcending in the Tube.

To all which I only add, what will hereafter be made more plain, that conformable to our Doctrines, when the Preſſure of the Body E, F, upon the ſubjacent Water, is a good deal encreas'd by the Weight of the Stone which is hanging to it; there is no Occaſion of a Valve as before, to elevate it above the Plan I, K; for the overcoming the Reſiſtance of the Water, when it is ſo built as to be capable of performing that by its own Force, before it can be elevated to its proper Height, which is all I ſhall in this Chapter add from this illuſtrious Author.



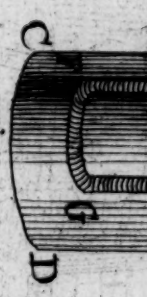
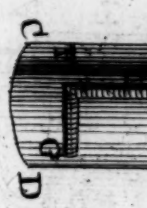


Fig. 16

Fig. 17

Fig. 18

Fig. 19

Fig. 20

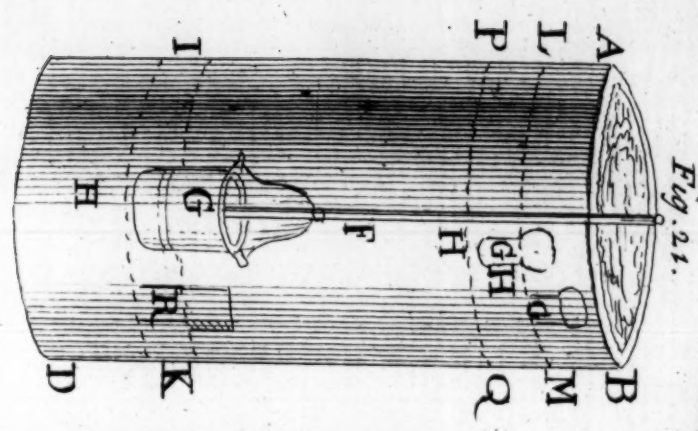
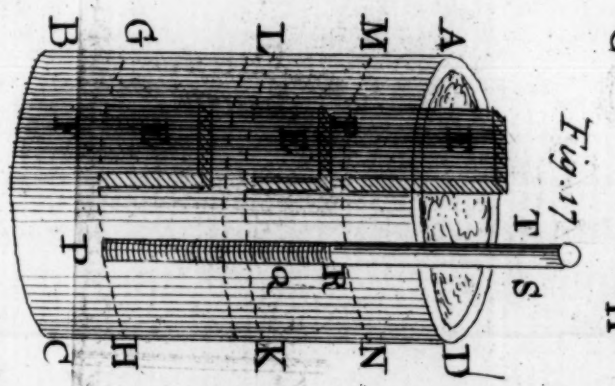
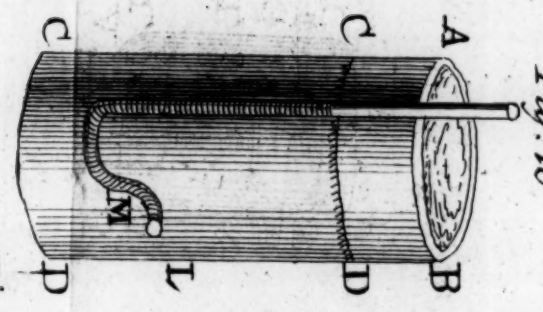


Fig. 21

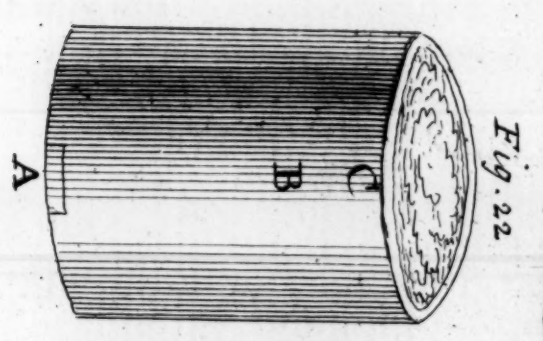


Fig. 22

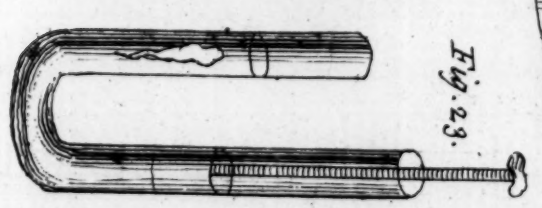


Fig. 23

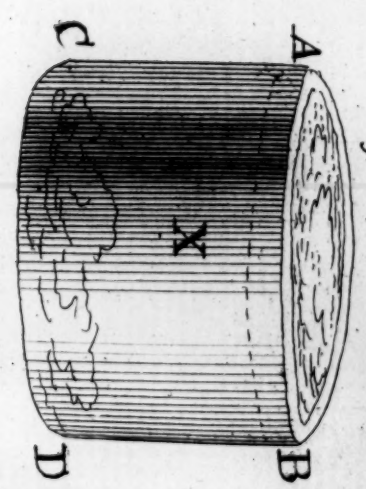
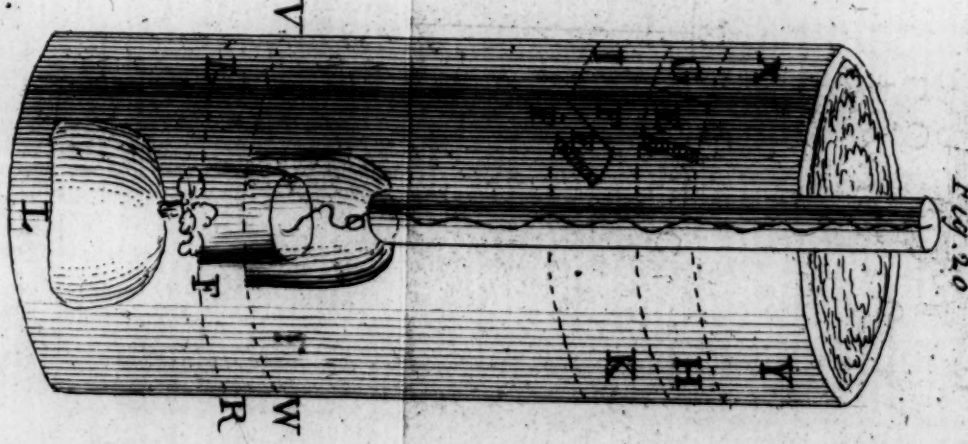


Fig. 24



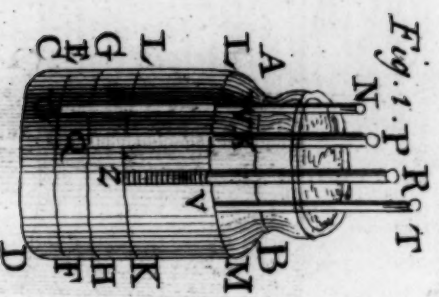


Fig. 1.

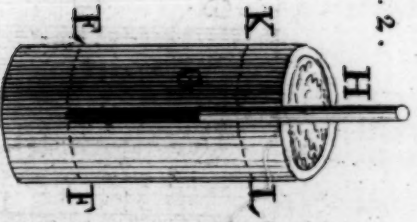


Fig. 2.



Fig. 3.

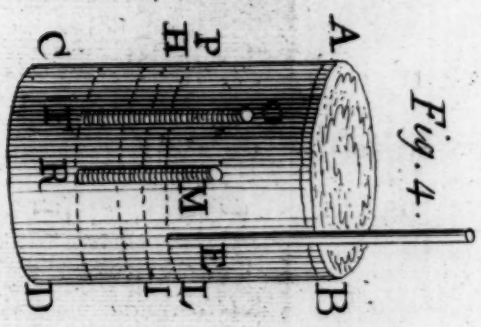


Fig. 4.

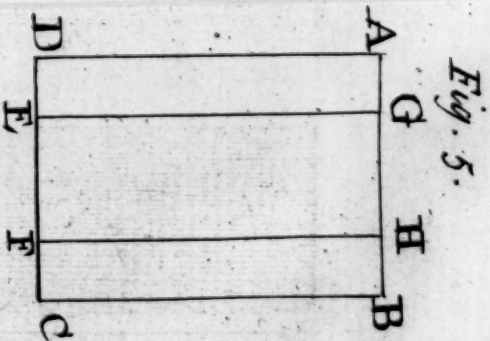


Fig. 5.

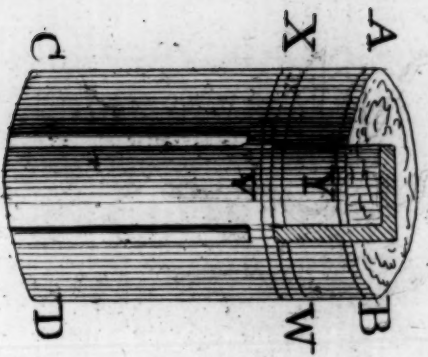


Fig. 6.

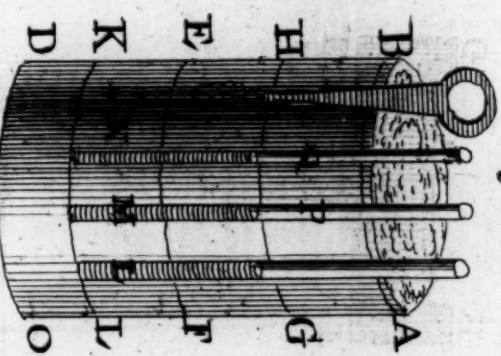


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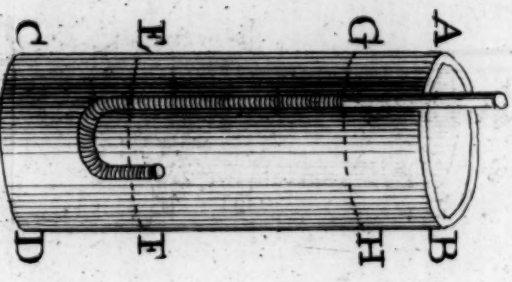


Fig. 8.

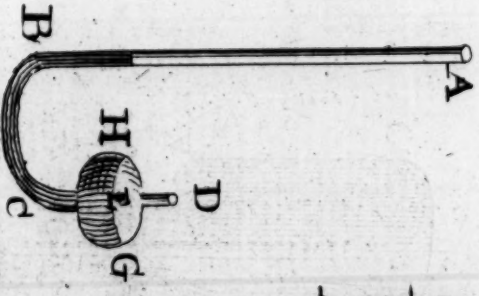


Fig. 9.

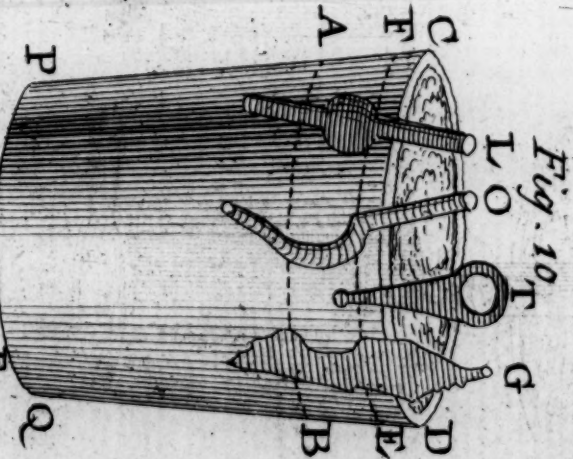


Fig. 10.



Fig. 11.

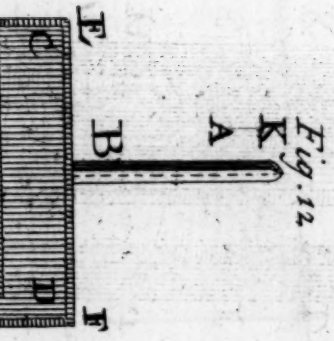


Fig. 12.

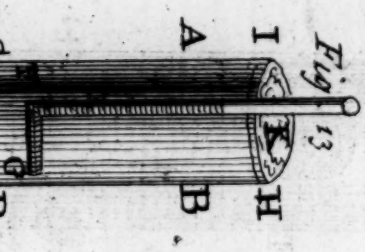


Fig. 13.

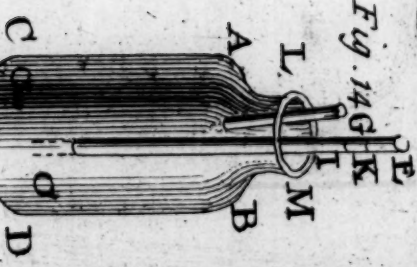


Fig. 14.

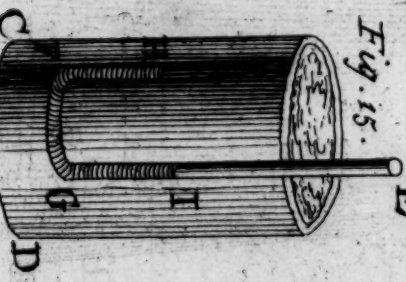


Fig. 15.



B O O K. II.

C H A P. XIII.

Of the so much disputed Vacuum of the Ancients, and of the natural Effects of Air and other Fluids in Hydrostaticks.



H A T I may explain what is meant by the *Vacuum* and *Plenum*, of which mention has been made in the foregoing Chapters, and which was for so many Ages the Dispute of a great many great Men; it is requisite I should trace and distinguish, with as great a Perspicuity and Plainness as I can, what the Advocates on either Side have advanc'd in Favour of their beloved Hypothesis; some whereof maintain'd an absolute *Plenum*, and the other as stiffly an absolute *Vacuum*, *Inane*, or empty Space; wherein otherwise they tell us *we can't move, for that one Substance can't move in another.*

I was once indeed in the Mind not to have gone so far back, as to have meddled with an Hypothesis which has been so long controverted, and till of late so little determin'd as this is; but then I thought I should not do Justice to my Subject, nor set this Affair into its true and genuine Light, without examining the most material of the Arguments *pro* and *con*, on which the Practice of Hydrostaticks and Hydraulicks are founded; being willing that those which must be obliged to tread these Paths, and to endeavour to get their Knowledge by Application and Books, as I have done, may have their Journey made as plain and easy as possibly it can be.

AMONGST the several Representations which many Sages of Antiquity have made use of, to assert the Improbability of a *Vacuum*, (which tho' stiffly maintain'd by some, was as resolutely deny'd

ny'd by others) was that remarkable Position for which *Aristotle* himself was the greatest Champion, *Quod Jovis omnia plena*: In which it was imply'd that all Hollows or supposed Vacuities were full of Air or some other Substance, (which still maintain'd the Doctrine of a *Plenum*) which Air was of such a Nature as to recede and give Place to whatever came into its Way, and then return again to its first Situation and Position, and that there was really no such thing as a *Vacuum* or empty Space in the whole Compass of Nature, which they demonstrated, or at least endeavour'd to demonstrate, by undeniable Arguments; and that it plainly appear'd by the bare Inspection of the Outside of a glass Vessel fill'd with Air, which being compress'd on every Side by the pouring in of Water produc'd so many extraordinary Effects; and this they produce as the Foundation on which so many useful Arguments are brought to light; for the better and clearer Demonstration of all that can be said concerning the Motion of Water by Engines or otherwise.

MANY there are (says the laborious *Bockler*, Lib. 1. Pag. 4.) of no small Note, which have endeavour'd to demonstrate that there is a *Vacuum* or Place empty and devoid of all Matter, from an Argument drawn from Quicksilver's being poured into a glass Tube, where it dilates or contracts itself, or, according to common Observation, rises and falls, as the exterior Air is more or less subtle or dense: But as the same Author observes, whenever they go about to do it by this or any other Argument, they appear to use those that are artificial or mechanical, rather than those that are natural, and therefore of little or no Use at all.

Democritus and *Leucippus* (as we have it from the same *Bockler*) being of the first Rank of the *Pythagorean* Philosophers, did suppose that there was nothing else but a *Vacuum*, or empty Space, which separated and divided ordinary things, and which was this large Vacuity in which we live; and then affirm'd that the World was a large Animal, from whence this Vapour-spirit or Air extended itself *ad Infinitum*, which they say was a clear Demonstration of this *Vacuum*, and suppos'd that this Action was first perform'd by the voluntary Aspiration or Breathing of this Globe, and *e' contra* draws in again by its Respiration.

Anaxagoras (by Name) another Philosopher of great Account, suppos'd also that there was a large *Vacuum* in the Place where we suppose the Air to be invisible to human Sight, and demonstrates that there was nothing in Nature more real and plain; by
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an Example of a Bladder's being blown up and extended in such a Manner, that it could not without great Difficulty be compress'd again.

AND the same laborious Philosopher endeavours to illustrate this his Opinion by another Example of a Watering-siphon. This Instrument says he, which is acuminated or pointed towards the Top, and made of Clay or any other Material, and used, as it often has, for the watering of Gardens, is in the Bottom very large and plain, but full of small Holes like a Sieve; but at the Top the Orifice is only one large Hole.

THIS Vessel, by the Intrusion of Water or Vapour passing through the open Spaces of the Bottom, is easily fill'd therewith, which otherwise it would not be, were it not for the large Orifice that is at Top by which the Air passes and is excluded, being resisted or stop't out by the superior Substance, Body or Force of Water passing in or through it: And in like Manner a Vessel full of Water, if it be shut or cover'd over at Top, and for that Reason the Entrance of Air is deny'd the Water that is poured in, nor any thing else will flow out below; because, according to *Anaxagoras*, nothing but Air, a Substance nevertheless invisible, can thus pass.

BESIDES these Philosophers, *Melissus* also upon the Foot of his own Experience proceeds to demonstrate a Vacuity from the following Reasons; all things (says he) that are moved or encreas'd, are moved and encreas'd in a certain or determinate Place; that this Place is either a *Plenum* or a *Vacuum*; if it be a *Plenum*, there will be two, three, or four, or perhaps an Infinity of Bodies in the same Place, the greater must be contain'd in the lesser, the equal and unequal in the same Place, which are amongst the Contradictions and Impossibilities of Nature.

FROM whence he argues, that all Motion and Augmentation happens in this Vacuity, and that such a thing is necessarily imply'd in the very Nature of things; for the moving of all Bodies therein, on which also (in the Opinion of this Philosopher) is establish'd the Certainty of the Moveableness or Rotation of the World, and to suppose that this universal Motion could be effected any where but in a *Vacuum*, would be absurd.

FROM hence he infers, that it is as plain as Light itself, that every *Plenum* or corporeal Substance necessarily has its Being in the Place of another apparent Body, which, says he, is in Truth no other thing but that memorable *Vacuum* by him as well as others so much contended for.

HAVING thus given a short Account of the Opinions of *Democritus*,

motritus, *Leucippus* and others, who have been endeavouring to establish the Doctrine of a *Vacuum*; *Aristotle* descends the Stage arm'd with four different Arguments, which nevertheless (for Brevity Sake) *Lampsacenus* contracts into two; one that relates to the Motion, and the other to the Constriction or Condensation of Bodies.

IN the first Place (he says) that he can't follow that Maxim, which implies that Motion being once allow'd, a *Vacuum* also must follow of Course; for altho' it is certain that nothing can move in a *Plenum*, yet the Methods are to be observ'd whereby Bodies give Place to one another, and relinquish Space to Motion, or in other Words interchange the one for the other.

So it is that a Stone which is thrown up into the Air is said to be mov'd, not as tho' it was in or through a *Vacuum* or void Space, but so as that the Air is lighter and more penetrable than other Bodies are, and so gives Place to a greater Force, and then after that returns to its former Position, even as the Sea gives Way to a loaded Ship, which, tho' it plows the Water and seems to leave a Furrow behind it, soon fills up again and returns to its former Level.

As to what relates to the other Argument, it is very weakly inferr'd from the Compression of Bodies that there is a *Vacuum* mixt with them, which suffers Bodies of a thinner Substance to be so constricted; for says that learned and intelligible Author, every thing which is condens'd is contracted or compress'd one within another, as it contains a Body of a more subtle Nature, which being compress'd in the aforesaid Manner passes through the same Pores or Perforations in which it was before found, giving Place to the Contraction and Condensation of larger and heavier Bodies, as we see Air evaporates and diffuses itself when compress'd by the more powerful Body of Water, the Weight of Water to that of Air by several later Experiments being found to be between 8 and 900 to 1; as Dr. *Desaguliers* and others have set down.

THAT which they urge from the Dilatation, Augmentation, and Rarefaction of Bodies, and that would infer from thence (as the learned and laborious *Bockler* has it) that the *Vacuum* resides amongst those Principles, argue (contrary to what later and better Philosophy teaches) what is very absurd and without any real Sound or Signification; for indeed this Kind of Augmentation happens by the Accretion of some other new Magnitude on the former, or that I may speak more intelligibly, by the Revolution, Union, or Joining (call it which you will) of a thicker Substance

of Hydrostaticks and Hydraulicks. 169

on that which is thinner; even as Air, which (as he says) is generated by Water, is by far more extensive and fuller of pristine Humor: Although no new Substance shall have any Accession or Addition to it, for which he refers to *Cornel. Drebblinu's Tracts of the four Elements*; and also *Benj. Bran. de Vacuo*.

THE Argument that is fetch'd from Ashes, turns it self against its own Authors, (says this laborious Philosopher) for whilst Ashes receive and sup up Water; they intromit it, either into a *Plenum* or a *Vacuum*; into a *Plenum* they can't, because, according to their own Opinions, one Body cannot penetrate into another; it therefore follows, that it must be received and admitted into a *Vacuum*.

BUT if we should by Way of Concession, and to please those Gentlemen, allow an absolute *Vacuum*, it would infer no more than that that *Vacuum* (which is really nothing at all) encreases and decreases, is dilated and contracted, which is an Absurdity; for upon such a Supposition, that this *Vacuum* could extend and contract it self like a Substance or Body, it would thence follow, that it was one and the same Thing that a Body was; and therefore nothing different from a *Plenum*, by which Means they destroy the Doctrine of a *Vacuum*, when they go about to establish it.

AND that the Argument concerning Ashes, (which the Advocates for a *Vacuum* make use of) is making rather against, than for them; *Eridemus* in his third Book *De Causis Naturalibus*, thus solves, stating the Case thus, That tho' Water be poured on Ashes, it does not follow, that that Water can be received, or, as it were, absorb'd and lick'd up thereby; for if there should be any vacuate Pores or Angles which imbibe the Water in such a Vessel, yet in Ashes, or, which is much to the same Purpose, slack'd Lime there is always a certain inward Heat, labouring as it were in its own Bowels which, when it meets with Moisture, causes it to change as quick as Thought it self, and evaporate into Air, which appears plainly to the Eye, by the Ascension of the Smoak and Vapour.

ANOTHER Reason made use of by the Advocates for a *Vacuum*, *Aristotle* himself solves in his Problems; and in this Manner he asks why Wine, that is beforehand sufficient for the filling of a Hogshead, but being poured out of it into glass Vessels, can't fill the same again, but leaves Room for pouring in more at Top. This Question (I say) this great Philosopher answers himself, by saying, That Wine contains in it self a certain Quantity of Spirit or Air, which the Thickness and Largeness of
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the Vessel does not so easily give Leave to evaporate or let go, as Glasses do; out of which being poured, by little and little, that which is poured off loses its aerial Spirit, and gives Room and Space for the pouring in of more Wine to fill it up: And I add, that when this Spirit or Air is evaporated, that then it is that Wine and other Liquor grows dead and flat, the aerial Spirit being evaporated and gone, that contributes so much to its Briskness.

To proceed with this laborious Philosopher, it is evident, that Air and Water separate themselves with more Difficulty from a large Body than it does from a small one; as a large Sponge that is fill'd with Moisture, cannot be freed from it by squeezing so exactly, or with the same Ease and Dispatch, as it will from a Sponge of a less Amplitude; and certain it is (says he) that Wine contains more Air than Water does: And it may be added from Experience, that the more generous Liquor is, the lighter it is; containing more Spirit as before; which also, says our oft-quoted Author, agrees with the Experiment concerning Ashes; to wit, that whilst the same Quantity of Water and Ashes are put at one and the same Time, into one and the same Vessel; it takes up the same Room, and no more than it did before, separately and successively (which; says our ingenious Author, is very easy to understand) for Ashes, being a very light Substance, contains in its own Pores and Recesses a great Quantity of Air; upon which Water being poured, which is more subtle and thinner than the terrene Substance of Ashes, insinuates it self thereinto, and by Degrees contracts more Strength (because every Thing which is compress'd, sensibly and by Degrees, and not by one Force only, is heavier and of greater Density in its own Nature, than that which is lighter.) By which Means Ashes naturally condense Water, whilst it is absorbing or drinking it up; and at the same Time evaporates a great Deal by Steam into Air, (if they are hot) that they may make Room for what remains.

BUT to draw as soon as possible towards a Conclusion of these Opinions of the Ancients, which are something hard to understand; there were many more (says *Bockler*, Lib. I. p. 7.) amongst those Sages of Antiquity, and such as were well skill'd in Philosophy, even as many as liv'd from the Time of *Thales* the *Milesian*, to *Plato*, that absolutely deny'd that there was such a Thing as a *Vacuum* in the Universe, from whence came that famous Verse of *Empedocles* of *Agrigentum*.

Nil Vacuum in toto est plano, aut circumfluit Orbe.

Yet altho' *Aristotle*, that Prince of Philosophers, appear'd to have banish'd the Notion of a *Vacuum* out of the World; yet *Plutarch* writes, that he held there should be as much *Æther* as Fire, for the sake of Breathing: However, as there are no Footsteps found in any of *Aristotle's* Writings, that tended thereto, but on the contrary, (and in Opposition to the *Pythagoreans*;) he is every where found stemming that Opinion of theirs, with all the Might he could, it may be infer'd that he held no such Thing.

Macedonus Epicionus, a Philosopher of *Etruria*, was of another Opinion, and says, That this *Vacuum* was placed without or near the Confines of the World, telling us that there are a Multiplicity of Atoms fluctuating and confusedly extending themselves under this *Vacuum* or empty Space, into which *Vacuum* upon any Occasion, (as may be infer'd from his Writing,) those lower Particles of Matter intrude themselves, when agitated or disturb'd by any potent Body.

To give this Hypothesis its due Emphasis and Weight, he says, That God Almighty is the Giver and Upholder of all Things, within this habitable World; but that which is without or above it, is the Seat and Habitation of that glorious Being, without any Limit or Substance, corporeal or immaterial, of eternal Duration; and this (with how great a Probability of Truth I know not) he terms a *Vacuum*; from whence he has infer'd, that this *Vacuum* or empty Space is not admitted within the Confines of this aerial World, for there being known Bodies of a like Nature, full of all that is proper to their respective Beings, and compos'd out of heavenly and celestial Elements, can't after that admit of any Thing, contrary to the Nature of what he had before set down.

Of this Opinion also was *Cleomedes*, a noted Philosopher of Antiquity; against all which *Aristotle* descends the Stage again; but as the Squabble is long, and the Arguments on each Side are manag'd in a kind of a confus'd Manner, rather than that which is Mathematical and self-evident, I shall not trouble my Reader with it. But shall only, to what I have said on this Head, add from later Times, the Opinion of *Hero Alexandrinus*, a noted Writer in Hydrostaticks, who says, That there were in his Time a great many amongst the Learned, that deny'd any Kind of *Vacuum* in the World: But for my Part, says he, I do agree and establish it as my Opinion,

172 *An Introduction to a General System*

nion, that there is such a Thing, but that it is not gathered together in one Place, but minutely and by insensible Particles, or small Parts, disseminated and dispers'd this Way and that Way, thro' Water, Air, Fire, and all other Bodies.

FOR altho' a Diamond, which, because of its natural Hardness, cannot be penetrated either by Fire or Steel, (certainly from the Reason and Proportion of it) yet it does not follow, that this Diamond is destitute of all Vacuity, but that it maintains its constant and impenetrable Hardness, from a thick invisible Substance.

FOR the fuller Demonstration of this Position, it is to be observed, that Air is a Body compos'd of minute, very light and inconspicuous Particles or Atoms, which mutually, firmly and in all Places cohere to one another, but yet leaves some small vacant Spaces within it self, in like Manner as Sand is gathered and heaped up together on the Sea-shore. Suppose then these Arenula's, or small Grains of Sand, to be Atoms or Particles of Air, you will perceive a soft gentle Wind or airy Substance in the Place of the aforesaid *Vacuum*; from whence it often happens, that by the preternatural Compression of those two Bodies, the included Air is of Course condens'd, and oblig'd to reside in those Vacuities or empty Spaces; but as soon as this compressive Power is remitted or relaxed, it immediately returns from what it was to its first State and Magnitude, as is seen in bended Horns and dry compress'd Sponges (the Power or Force being over, whereby they were compress'd) which, according to their own natural Affection, return to their former State and Place.

ALMOST the same Effect follows, where Particles of Air are emitted or chas'd away out of any Place or Vessel, by any extraordinary Violence, for that they quickly flow together again, from an innate Affection that is in their Nature one to another, and lest the *Vacuum* should extend it self beyond its just Bounds; for this Motion, or rather Flight of the Particles of Air, accelerates (if nothing else hinders) this very *Vacuum*. For we find by every Day's Experience, that if any light Vessel having a narrow Orifice or Mouth that moves, it attracts the Air with it in a very strong Degree, and if you apply your Lips to it (lest the *Vacuum* should have too much Space) it will adhere to them, contrary to its own Nature, that the suppos'd *Vacuum* may be completed and fill'd the better; and the same Thing happens in a Syringe, which is us'd in sprinkling or dispersing of Water or Moisture over any Thing; as also in all Cucurbits or Cupping-Glasses,

Glasses, us'd in common Scarifications, as is easily demonstrable to the Eye.

AND that this may be the better understood, (our Author argues) that the Cover of a Brass Vessel being made very strong and hollow, or of a spherical Figure within, and which will hold one and a half, or two Measures of any Thing, and let it be every Way well shut and conglutinated or sealed together; make a Perforation or Hole, on the Top of this spherical Vessel, and put down therein a Tube perpendicularly; but so, as that it may not touch the Bottom, but have a necessary Space for the Water to fluctuate: Let this little Tube be carried higher than the Vessel, and the Bung-hole of the Vessel exactly stop'd three or four Fingers thick, or more, as it is done in all other Cases of this Kind: If therefore, according to the Opinion of some, there is no *Vacuum* within this Sphere; it consequently follows, that there is neither Air nor Water in it, and that it is a *Plenum*.

BUT this is not so, for if the aforesaid Tube be mov'd to your Mouth, and you adjoin it thereto, and blow with what Strength you can, all, or a great Part of the Air that was before enclosed in the Vessel, will pass, and hurry out with great violence: From whence it must be infer'd, that there is a Kind of *Vacuum*, or empty Space, wherein that Air was included; which, as was said before, was condensed and contracted, and might admit of more; or if you would have it otherwise express'd, when you have suck'd out one Part of the Air, in the Room of which no other can be admitted, it is necessarily and consequentially imply'd, that there does remain a certain *Vacuum*, though not such as has been often understood within this spherical Vessel; but so, that it may be easily increas'd or extended by Resuction. From all which it is evident, that there are vacuated and dispers'd Spaces in the Air, by the Intervention of which, it may be condens'd, rarify'd, or expanded: All which tends to what our more modern Philosophers set down on this Head, who have distinguish'd it into a *Vacuum disseminatum sive interspersum*, &c. Having thus trac'd the Opinions of the most knowing amongst the Ancients, let us now have Recourse to what our more modern Philosophers have argued on this Head.

Robault, one of the chief amongst the *Cartesian* Philosophers, (for I have not had the Opportunity of examining what *Descartes* himself has advanc'd, (Part. I. Cap. 8.) as we have it from that excellent Version of Dr. *Clark's*) affirms, that there can be no such Thing,

Thing, as what the Philosophers call an *inane* (*) or empty Space, since by that *inane* they understand a Space without any material Body in it; but to us, (says he) Space and Extension is one and the same Thing; and that to enquire whether Space can be without Matter, is to enquire whether Matter can be *sine materiâ*.

BUT that excellent Divine, who by his great Learning has been such an Honour to his Country in general, as well as a great Benefactor to Philosophy in particular, positively affirms from the Nature of Gravity, that there is such a Thing as a *Vacuum*, and which is greatly visible in all sublunary Beings. And, upon the Foot of the *Newtonian* Principles, proceeds to demonstrate it from the Motion of Comets: For when Comets, says he, are by any long continued Motion carried every Way, and in all Parts through the celestial Spaces above, (they necessarily cut the Orbs of all those Planets they meet with cross-wise) from whence it is evident, that those celestial Spaces are free from all sensible Resistance, and consequently free from all sensible Matter, and which also (I may add) necessarily implies a *Vacuum*.

THE same Thing holds good of pendulous Bodies, for that Bodies of this Kind meet with no Resistance, where the Air is not exhausted; from whence it is plain, that there is no sensible Matter in those Spaces, or in the occult and hidden Meanders of those Bodies: The *Cartesian* Supposition, that the Thinness of any subtle Material, (suppose Air) may be the Cause why its Resistance is not sensible; and that a small Body running upon, or meeting one which is greater, can't move it at all, or any Way hinder its Motion, but that it will reflect back with all the Expedition imaginable, is foolish, and contrary, both to Reason and Experience.

FOR the most illustrious *Newton* has demonstrated, (in his *Opticks*, Pag. 311.) that the Density of all middle Fluids answer in Proportion to the Resistance of those which are next them; and it is a great Mistake of those who hold, that the Resistance of Projectiles diminish *in infinitum*, thro' the infinite Division of the Parts of a Fluid; when on the contrary it is visible, (*vid. Princip. Lib. 2. Prop. 38. Coroll. 2.*) for that the Resistance which is occasion'd by the Division of the Parts of the Fluid, can't be much diminish'd; because it appears, (by *Prop. 40. Coroll. 3 & 4.*) that

(*) *Inane* quod vocant Philosophi nullum esse posse spatium sine Materiâ, nobis autem spatium (seu Extensio) unum & idem est atque Materia, & quærere utrum spatium sine materia possit esse tale, est quale si quæras utrum Materia sine Materiâ possit esse. Vid. *Robault's Confectaria*, Pars prim. Cap. 8.

of Hydrostaticks and Hydraulicks. 175

the Resistance of all Fluids is as their Densities ; for why can't the same Quantity of Matter have the same Force of Resistance, when they are divided into a great many small Parts, as a few that are larger ? Wherefore, if there were no void Spaces, it would follow, that a Body which is cast into the Air, or into a Place out of which the Air is exhausted, ought not to move with less Difficulty than in Quicksilver, which is contrary to Experience. And it is plain from the Nature of Gravity, (†) (as before asserted) that that Space is an *inane* or empty Space, and such a one indeed as abounds in all sublunary Things.

WHEN therefore the Essence of Matter is founded not in Extension, but in impenetrable Solidity ; it must be said, that the whole World is compos'd of solid Bodies, which move in *vacuo* : Nor is there any Doubt to be made ; but that the Phænomena's of Nature may be as well explain'd by this Principle, as any ; for the Explanation of those Phænomena's, which seem to have the greatest Weight in the Plenitude of the World, as the *Barometer*, the Flux and Reflux of the Sea, the Motion of the Stars, Light, &c. are very plainly demonstrated from them.

OF the same Opinion also, is the learned Physician Dr. Cheyney, who in his Principle of reveal'd Religion, (*Cap. 2. Coroll. 5. Pag. 12.*) by the *vis inertiae* of Sir Isaac Newton, says, that the Necessity of a *Vacuum*, or a Place distinct from Matter is clearly demonstrable ; all Bodies (according to that learned and ingenious Author) resisting, to the utmost of their Power, any Change or Alteration of their State, whether of Motion or Rest. And since the Resistance in the same Body is always equal or the same, and in different Bodies (as before-mention'd) is proportionable to the Quantity of Matter they contain ; and that since, consequently, if two Bodies, containing equal Quantities of Matter, and moving with equal Velocities in a contrary Direction, so that they impinge directly on one another, they will certainly stop at the Point of their Concourse and be at rest.

As also, since it is demonstrable, that two Bodies moving contrariwise with equal Celerities, and resting both at their Meeting, are equally heavy ; it necessarily follows, that two Bodies containing equal Quantities of Matter, are equally heavy ; and therefore, if there were no Vacuities in Bodies, two Spheres of equal Diameters would contain equal Quantities of Matter,

† Vid. Not. 1. Lin. 4. Verum ex Gravitatis Natura constat jam omnino aliquod inane & multo id quidem maximum in rebus esse.

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and consequently be equally heavy; *i. e.* two Spheres of equal Diameters, one of Gold, and another of Wood, should have the same specifick Gravity; which being contrary to Experience, there is a Necessity of admitting Vacuities in the later Sphere, to answer the Difference of their Gravities.

IT is true (says that learned Physician) it may be answered that one of the equal Bodies may be suppos'd to be more porous than the other, and the Pores to be pervaded by some more subtle Fluid (suppose Air) which passing freely thro' the Body, is not concern'd in the Impulse. But to obviate this Objection, and to make the Proof of a *Vacuum* amount to a Demonstration, Sir *Isaac Newton* has shewn by many repeated Experiments in Pendulums, &c. but particularly in descending Bodies, that the Resistance of Fluids (as we have already set down from the Reverend Dr. *Clarke*,) is always proportionable to their Densities, that is, to the Quantities they contain, or to their *Vires inertiae*, which this Physician urges from the Resistance and Pressure of Fluids one upon another: And since it is Weight alone (*i. e.* Matter) which can produce Pressure in all inanimate Bodies, (for which see *Newton's* Schol. on Prop. XL. Lib. II. second Edition of his *Principia*) it is plain, that if Bodies be ever so porous, and fill'd with Fluids ever so subtle, yet if there be no Vacuities entirely without Matter, those porous Bodies must be equally heavy with the most compact ones; since the Fluids requir'd to fill those Pores, must be equally heavy with the solid Body; and since both must contain an equal Quantity of Matter, if there be no Vacuities; all Fluids resisting (that is indeed weighing) in Proportion to the Quantity of Matter which they contain. If therefore there be no Vacuities, Bodies must be equally heavy, which being contrary to Experience, there is a Necessity of admitting Vacuities, in order to account for the all different corporeal Weights.

BUT there is another also, of our modern * Philosophers, who, upon the Foot of the *Newtonian* Principles, allows of the Possibility of a *Vacuum*, from the bare Examination of Ideas, for that every Thing which we can clearly discover to exist, is possible.

WE acquire (says that learned Author) an Idea of Solidity by the Touch, and we feel Bodies that resist us every Moment, by

* *Vacuum possibile esse ex solo examine Idearum deducitur, omne enim quod clare concipimus existere posse, possibile est, (ut vult Gravesande. Math. Elem. Nat. Philos. Cap. 3. Lib. I.)*

which it appears that a Body is solid; which Ideas of Solidity are transferr'd, even to those more subtle Bodies, which, by Reason of the smallness of their Parts, escape our Senses; (as Air for instance, in which, as will be hereafter found, are several vacuate Spaces) and we find by Experience, that even these of Air, subtle and thin as they are, resist other Bodies as well as the hardest.

THUS the Air we are speaking of, does, almost, always escape our Sight and Touch; yet in a Syringe, which is close shut up at the End, it resists the Piston, so that it can't be push'd to the Bottom of the Syringe by the greatest Force.

THE Idea of Solidity (as defin'd by this excellent Person) is not indeed contain'd in Extension; that only follows from Contact, but this may be had without it; for if a Man had never touch'd a Body, he could have no Notion of Solidity.

AND indeed all or most of the Squabble that has been between the Philosophers, both ancient and modern, has been occasion'd by their different Conceptions of the Nature, Properties and Accidents of Matter.

Aristotle in his *Physicks*, writes that Matter is *nec Quid, nec Quantum, nec Quale*, neither can it be defin'd in any other certain Manner; from which most of his Followers inferr'd, that it was not capable of Extension, nor did it even exist; tho' *Robault* in his *Physicks*, *Cap. 7. Pag. 23.* says, 'That *Aristotle* appear'd to speak of Matter in general Terms; besides as he there distinguishes Extension from Quantity, every Body ought to distinguish carefully between them, because one can't know one without the other.

I shall omit the Accidents of Matter, which are Hardness, Liquidity, Cold, Lightness, Taste, Smell, Sound, Light, Colour, &c. which the *Cartesians* suppose have no Parts, Figure nor Extent; and last of all, as to the penetrable Nature of these Accidents: If any Part of Matter, to wit, a Foot cubick, tho' it has all Things that are necessary to that Magnitude, yet it does not appear that another Foot cubick can be added, but that of it two cubick Feet must be made; and as he that is willing to reduce them by Penetration, both into one cubick Foot, yet nevertheless could not join one to another, unless he should overturn that which he had first fix'd; upon which Account it was, that the *Cartesians* believed, that the Parts of Matter are impenetrable in their Nature.

WHICH Things being so, it must be inferr'd, that Extension, Figure and Impenetrability, are truly the Properties belonging to
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178 *An Introduction to a General System*

the Essence of Matter, which constantly attend it; and from which it can't be separated: But because Extension is to be conceiv'd prior to the other two, and that neither of them can be well conceiv'd or understood, unless Extension be first, it is to be suppos'd that this Extension is that which constitutes this Essence or Being of Matter.

BUT Dr. *Clark*, in his Notes on *Robault*, says, That if Extension was the essential part of Matter, and that that Matter was the same as Space it self; it would follow also that Matter (as Space) was infinite, and consequently eternal, which does not depend on created Beings, nor can be any Property or Consequence of them, much less a Mode or Accident, and therefore it must be a true Substance. * Besides, (says our learned Divine) by the Nature of Gravity, (as before defin'd) by the Motion of Comets, and the Vibration of Pendulums, it appears plainly that Space it self can't be Matter; † and therefore that not Extension simply consider'd, but such an Extension as is solid, impenetrable and endued with the Force of Resistance, can (as before said) be call'd the *Materia Essentia*, or the real Being or Essence of Matter.

Now as the Extension of a Body implies a Divisibility, that is, that one may consider Parts in it, but yet the Divisibility of Bodies differs from the Divisibility of Extension (according to *Gravesande*, Book I. Pag. 8.) for its Parts may be separated one from another; but as this Property depends upon Extension, it must be examin'd under the Consideration of Extension, and then what is thus demonstrated may be easily transferr'd to Body.

BUT to come nearer the Point, and not to detain my self nor Readers in a Labyrinth, concerning the Parts whereof Matter is compos'd; it is in general certain, that many of the Particles of Matter are of a very subtle insinuating Nature as Air is, which tho' it does insinuate it self into all the Crevices and Recesses, into which it can find Entrance; yet that there are Vacuities, even in Air it self, I shall by and by demonstrate.

By the Help of Microscopes many Objects, which would otherwise escape the Sight, appear very large, and there are some Animalcula so small, that they are scarce visible with the best of these Instruments;

* Ex quo manifestum est eam à rebus creatis non pendere; nec posse earum consequens, nec proprietatem; multò minùs Accidens, aut modum; ideoque veram esse substantiam. Vid. Cap. 7. pag. 23. prædic.

† Quare non *Extensio*, sed *Extensio solida*, impenetrabilis & vî Resistendi prædita, rectius (ut dictum est) appellari poterit *Materia Essentia*. Vid. Dr. *Clark's* Notes on *Robault's* Phys. Part I. Cap. 7. pag. 22. in finem.

and yet these have all the Parts necessary for Life, as Blood and other Liquids: How wonderful therefore must those Particles be, which make up such a Fluid!

BUT at last, and to conclude this Chapter, these Parts, however subtle they are, are certainly intermix'd with vacuate Spaces, which proceed from the nature of their Figure or the stricter Union and Coherence or Incoherence of them.

I imagine therefore that Air is compos'd of an infinite Number of Corpuscula's, and small Bodies or Particles of Matter interspers'd thro' the whole Region where we live, of the Nature, (tho' invisible) of Sponge, Cotton, Hair or Wool, or of that Down which is on the Top of the *Sonchus Levis*, or *Southistle*, or of the *Erigerum Tomentosum* or *Groundsel*, which feeds so plentifully in Gardens.

WHETHER the Figure of these Particles of Air be globular and smooth, or irregular and so glabrous or uneven, I shall not at this Time take up my Time in discussing; it is evident, that let them be which you will, and let the Substance of them be fram'd in the Nature of any of the Substances abovemention'd, that in all the Unevennesses that must necessarily flow from their Contexture, Shape and Figure, there are Interspaces, wherein that *Vacuum* resides.

EXCEPT we were to suppose them to be Bodies of the Figure of a Die, us'd in Gaming, which, nevertheless, would by their Revolution (had they Room to turn) soon wear off their Corners. Nor is it to be doubted, but that those Particles of Air are not very strictly hook'd together, but flie as it were separately and disjointed one from another; at least if there be any Connection, it is only that, by which the Tops of the Apices or Tufts of these Semens are joined to one another; and it may with Reason be suppos'd, that these vacuate Spaces which are dispers'd between them are larger than those Corpuscles themselves are, and much beyond the Reach of Human Sight, and that those Spaces are very intelligibly (by Physiologists) defin'd by an interspers'd or vacuate *Inane*.

AGREEABLE also to this, is what the learned and laborious *Harrison*, in his *Lexicon Technicum*, has set down, who has distinguish'd it into a *Vacuum disseminatum* or *interspersum*, that is, large Vacuities interspers'd about or between the Bodies of a smaller or larger Fluids.

OR a *Vacuum coacervatum*, which is a larger void Space, made by the meeting together of the several interspers'd or disseminate Vacuities beforemention'd; and that there is in the Sense of these

180 *An Introduction to a General System*

learned Gentlement, a *Vacuum*, at least a disseminate one, seems clear from the following Arguments :

FIRST, that without supposing some interspers'd Vacuities amongst Bodies, 'tis very hard to account for Motion; for if there be an absolute *Plenum*, the least Body in Nature can't move, but all Bodies that are must move with it; and yet into what Places they should move, when all Things are already full, is very hard to conceive.

SECONDLY, Without allowing a *Vacuum*, how can there be any such Thing as either Rarification or Condensation; for if all Space is actually full of Body, nothing can possibly ever take up a greater or lesser Room than it had at first, and yet we find by evident Experience, that Air is capable of a very great Degree of Compression, and that Water may be rarified into Air or Vapour, and then take up vastly larger Room than it did before.

THIRDLY, Sir *Isaac Newton*, (as beforemention'd) has found that the Weight of Bodies doth, by no Means, depend on their Forms or Textures, but that all Bodies at equal Distances from the Earth do gravitate towards it, in Proportion to the Quantity of Matter in them, which is every where as their Weight; wherefore there must of Necessity be a disseminate *Vacuum*, for if all Places were full, there would be no Difference in the specifick Gravity of Bodies; but Air would be as intensively heavy as Gold; and so Gold could not descend in Air, much less any lighter Body than it, which would contradict all the received Laws of Hydrostaticks, tho' confirm'd by ten thousand Experiments.

To illustrate what we have been saying, from Example and Experiment, and to give this disseminated *Vacuum* (which is not altogether inconsistent with a *Plenum*) its due Emphasis, so as to discover its Effects in Hydrostaticks, we find that the Ancients (as the learned *Wallis*, P. 14. Prop. XV. of his *Mechanicks*) plac'd their Notion of a *Plenum*, and the Abhorrence which there was in Nature to a *Vacuum* from a Siphon, which being plac'd in a Vessel full of Water, and the Air drawn out of the Tube (as it is done in the decanting of Wine and other Liquors) that then the Liquor will follow immediately and keep running, till the Vessel was quite empty, at least till it was drawn down to the level of the End of the Siphon.

FROM which Phænomenon, it was (says he) that they grounded their Belief of an infinite *Fuga vacui*; and that consequently they could, by the same Method, convey Water over the highest Hills into opposite Valleys; but it was afterwards found out by

of Hydrostaticks and Hydraulicks. 181

undoubted Experiments, that Water could not be drawn above 33 or 34 Foot high at most, either by Suction or Pulsion (call it which you will) that that *Fuga vacui*, (as understood by the Ancients) had really no Existence but in the Minds of its profess'd Admirers.

ON this Account it was that some Moderns began to introduce the *Equipondium* or Counter-balance of Air, to that of Water, in the Room of the * *Fuga vacui*, so much before contended for; which they found would not do; in which the famous *Gallileo* first led the Way, shewing the Method of weighing and knowing the specifick Gravity of Air, compar'd with Water, &c. and which was from him pursued with great Sagacity by *Torricelli*, who invented, as a farther Proof of it, the *Barometer*, which from that ingenious Inventor, is to this Day, by the Learned, call'd the *Torricellian* Experiment; being a glass Tube of about three or four Foot long and one Quarter of an Inch Bore, seal'd and clos'd by Fire at one End, and at the other fill'd with Quick-silver, and then being stop'd with one's Finger, and having the unseal'd End of it thrust down under the Surface of other Quick-silver contain'd in any Vessel, and then the Finger being removed from the Orifice, and the Tube put into an erect Posture, the Mercury will descend or run out, till it remains in the Tube to the Height of between 28 or 29 Inches or more, leaving at the Top of the Tube an apparent empty Space.

I need but just add, that this Quick-silver, or any other spirituous Liquor, thus suspended, has been found to encrease or lessen its Height in the Tube, as the Weather alters for dry or wet; and by this Means it is, that the Weight of Air is known.

To go on with the learned *Wallis* P. 744. Fig. 321. of his *Mechanicks*, having suck'd out the Air at the End of the Siphon E in C, until it has made an *Equilibrium* or equal Poize, by the Pressure of the external Air, (as has been already noted) suppose to the Height C I, which admit to be 33 Foot high in Water, (and proportionably, according to the specifick Gravity of all other Liquors) if therefore the Top of the Siphon D be not higher than I, the Fluid will rise quite up to the Top, and having found out its Passage, will descend and flow out at E; and will continue always so to do, by repeating the same Methods.

* *Wallis* Cap. 14. Prop. 11. of his *Hydrostaticks*, asserts, Quod fugam illam non infinitam esse, sed intra certos limites coerceri; aerisque Equipondium in illius loco substituendum, &c.

BUT

BUT by the same Rule that E is lower than C (in the *Superficies* A C B) so are C and E compress'd by the equal Force or Pressure of the Atmosphere, if the Leg D E be of less Height than the Leg D C, and so the Fluid, which is in the first gravitating less, than that which is in the last; the Fluid would be carry'd by a contrary Course from E thro' D, even unto C, (the Air succeeding in E, except the Largeness of the Siphon is so great, that the Air might ascend by the Sides of the Fluid, whilst it was flowing thro' the End of the Siphon D E,) in which Case the Fluid might part in D, and one Part ascend by D C, and the other by D E, the Air ascending likewise thro' the Sides of the descending Fluid D E; but in narrow Siphons the Fluid is or would be carry'd back in E thro' E D C being driven by the urgent impulsive Air in E.

BUT if D be higher than I, the Fluid will be again forc'd from C, even to I, but no farther, nor will it ever reach to D; and therefore it remains, that the Suction ceasing, it continually flows thro' D towards E; but so as that it can't by any Means be drawn on to E; for when the Suction can't act any otherwise than by making a Place where the Fluid may be receiv'd, it is not properly suppos'd to be perform'd by Suction, but press'd on by the Impulse of exterior Air; but supposing that Room be made, the exterior Air can't, nevertheless, drive the Fluid any higher from D than to I, and the Fluid will there stand at I; neither can it be carry'd any higher, so as that it may pass thro' D to E, according to the Laws and Principles of Hydrostaticks.

AND indeed, if the whole Siphon E D C were to be fill'd by the Fluid, the Orifices being open in both of them, and a Partition made in D, that which is in the Leg D C would be depress'd, so as not to rise higher than I; neither can the Fluid at C be rais'd any higher than the other Parts A B C, and that which is in the Leg D E will flow out thro' E (Air succeeding in its Place) at least, except the Leg D E be so straight, as that the ascending Air can't pass by the descending Fluid, in which Case the Fluid shall descend in D E, and then up to the Height I, being there suspended, till the Air can sensibly insinuate it self, and a Way be made, by which the external Air shall (by that free Entrance) exercise its Force thro' E, and depress the Remainder, which was in the Leg D E, even to C.

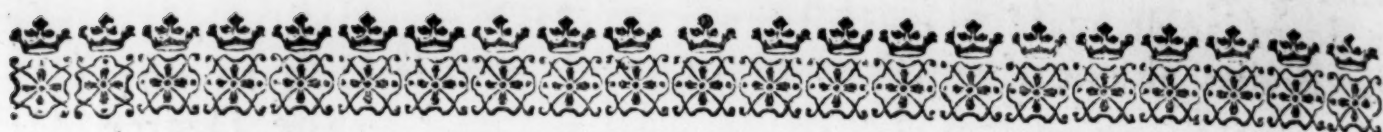
AND here indeed, the whole Story of the so long disputed *Vacuum* and *Plenum* are both brought out, which seems to be no more than this, that Air being of an elastick Quality, and compos'd of an infinite number of Corpuscles, which give Way, in Case

of Hydrostaticks and Hydraulicks. 183

Case they be compress'd or jostled out of their Places by any other Body harder or more weighty than it self, unbends, looses and restores it self again to its first State and Position, after such Weights or Bodies absent themselves again, and permit it so to do; and that this Elasticity is a Quality essential (at least in the Degree Air is) to nothing but it self, there being no Fluid that participates of it, in that Degree, but so far as it contains any of its Particles in the Pores thereof, and that the *Fuga vacui* is no other than that Elasticity with which Air is endued, which easily submits to be suck'd or drawn up to give Room for Water, which rises contrary to its own Nature, to the Supply of the so much dreaded *Vacuum*, by the Laws of Hydrostaticks, by the exterior Pressure of the more weighty Body of the Air of the whole Atmosphere, combining, as it were, together; and that there is, nevertheless, not a Recess in Nature where Air does not make up towards a *Plenum*, tho' not a real one.

To conclude, as I begun, with the laborious *Bockler*, (in the Enquiry I have been all along making concerning the so much disputed *Vacuum* &c. I can't but observe with what Patience and Judgment that exquisite Author has sum'd up the Arguments which have been deliver'd *Pro* and *Con*, by the Disputants on either Side, without shewing any Partiality or visible Dislike to either; yet he at last appears to be a Plenist, and when he is giving the Opinion of *Aphrodiseus*, he is a little warmer, and asserts *that there is no such thing as a Vacuum*, as describ'd by the Champions for it; but that *it was contrary to Nature, and that if such a Notion were allow'd, the Heaven and Earth, and all the other Elements would turn to Ruin and Destruction*; but this Mistake of his was certainly owing to the faint Ideas he had of Solidity, Extension and the like, of which so much has been said in this Chapter that I need not repeat it.





B O O K. II.

C H A P. XIV.

Of Air and its Effects in Hydrostaticks, by its Gravity, &c.



Shall in this Chapter omit that Enlargement on the Virtues and Effects of Air, (taken in a vegetative Sense) as such a noble Subject requires, because it is more properly physical, and so not altogether relating to the Subject I am upon; however, it may not be amiss to premise, that it is this which falls down and continually hovers on Fruit-trees and other Vegetables, where by the physical Operation of Nature it self, meeting with Dews, and other liquid Refreshments, it causes Trees and Plants, and whatsoever it falls on, to flourish and grow. Nor is this Union and Mixture of the Superior with the Inferior World, an imaginary, but a real and effective Truth; for from this Marriage (if I may so express it) both of Heaven and Earth, is produc'd all the Race of Vegetables, as well as Animals; 'tis this which cherishes old Age, and is the Cause of that charming Renovation of Youth, which is often visible in decaying Plants, Trees, and 'tis this which causes the Trees to leaf, bud and fruit, and to diffuse those generous Odours, with which it self is again (by a due and regular Circulation) perfum'd.

NEITHER shall I detain my Reader with any long Account of the great Controversy, which has happen'd between some modern Philosophers concerning Air; as whether with some, it be nothing else but those Exhalations which are drawn up out of the Earth, and so take Air and the Atmosphere to be one and the same Thing; whilst others suppose (that besides these Exhalations) there is hovering about the Earth, a certain peculiar simple Body, which they call Air; tho' they likewise agree that those Exhalations may

of Hydrostaticks and Hydraulicks. 185

may be chang'd into Air, and on the contrary Air may be chang'd into Clouds and heavy Vapours.

“ *Aristotle* and his Followers (as it is found in *Varenius* Prop. 3. Pag. 324.) divide those Exhalations into two Species or Kinds, (*viz.*) Vapour and Smoak. Vapours (say they) are generated of Water and easily return thereto: But Smoak is generated of things which are dry; so Sal Armoniac being put over a Fire goes off in Smoak, and this is the Cause why different Air is found in different Countries; also why it rains in one Place and not in another.” (*Viz.*) to the Siccity that is in the subjacent Body and Bowels of the Earth, from which that Fume is suppos'd to arise.

AND this Definition of the Air into two Parts does not, I must confess, seem any Way disagreeable to Reason, and the small Observation I have made of things, tho' of what Figure those two Parts are compos'd, we are not well inform'd, by these or any Authors that are common amongst us.

THAT Air is of two Kinds, I guess from those drying Winds which are so prejudicial to all new planted Trees in *March*, when the Siccity or Dryness of it, is so predominant, as to destroy all the milky Fibres of a Tree, and whatsoever else it meets with that is young and tender; from which I say, I am convinc'd that Air and Vapour are two things; the first I take to be of the Figure of little Fleeces of Wool, which are always fluctuating up and down, in this otherwise *Inane* or empty Space, which Air is either more or less subtle or dense, according as the Nature of Heat and Cold is more or less, or that the Weather is in an intermediate State betwixt both.

THUS in the greatest Colds of Winter the Air is subtle and serene, whilst a more moderate Cold contracts and makes it more heavy and dense: Now it is the Density of the Air below, which raises up and suspends the Vapours above it; namely, till they settle in those Regions which are specifically equal to themselves in Weight, and this seems to be one Reason why (in high cutting cold Winds) the Air is sometimes dryer, than it is at others. And a second Reason may be, that as the Density of the Air suspends those Particles of Vapour (which is lighter than itself above) so it depresses all those which are below from rising; since it is demonstrated from the honourable Mr. *Boyle* in Paradox or Proposition viii. Chap. 12. of this Treatise; that *Water* (and I may add any other Fluid) *may be made to depress a Body lighter than itself as well as buoy it up.*

B b

BUT

186 *An Introduction to a General System*

BUT whatever that be, it is as *Robault* Part 2. Chap. 2. of his *Physicks* (as turn'd into *Latin* by the Rev. Dr. *Clarke*) has set down, that liquid transparent Matter which spreads itself upon this Globe of Earth and Water whereon we live, and that it must of Necessity be compounded of an innumerable Quantity of Particles of no certain Shape or Figure, spreading irregularly like the Boughs of a Tree; and that the Lightness of those Particles is such, that they are continually in Agitation, and tho' their Figure seems to be such and so dispos'd, that as often as they meet in Contact they might be join'd one to another; yet because of its Tenuity or Thinness, or from those other Particles of Matter which are continually pressing upon them, from the upper Regions, they are with the greatest Ease unbent and unfolded.

BUT because this Account of *Robault's*, (tho' finely drawn) seems to be rather physical than any Way mathematical; I shall substitute an Account of my own in the Place of it.

I imagine then that Air is compos'd of an infinite Number of corpuscular Atoms or rather fine transparent Threads or Fibres, (as before observ'd) like the small Filaments or Threads of Wool, Cotton, or any other hairy or tomentous Substance, or perhaps rather like those of Down, which grow on the Heads of many Garden Seeds, or the fine Icicles of a hoary Frost, the Shape of which is by some compar'd to the small irregular Branches of a Tree, containing in their Interspaces the Place where this *Vacuum disseminatum* (if I may so express it) resides.

THAT these Particles of Air consider'd by themselves have no centrifugal Force, nor do they cohere to one another is evident by that easy Transition that is made by the Impetus of any stronger Body through them; for tho' by their Figure they may seem well dispos'd for such an Union; yet this never is effected on Account of the Thinness of that divided Matter of which they are compos'd, the Branches also being so short and thin, that they can't well be knit together; that this Air is always liquid and never grows hard as congeal'd Water does; that it is light is because there is a great Rarefaction in it, and that it is transparent must of Necessity be, that those Rays of Light which proceed from the Sun may have their free Passage, all which are amongst the Suppositions of all who have wrote of Air.

BUT of whatever Parts or Particles of Matter Air is, it is when compos'd and taken together call'd the Atmosphere, an Appellation well known and often made use of in hydrostatical Experiments,

of Hydrostaticks and Hydraulicks. 187

periments, and is no other as * *Varenius* has it, than the Texture or weaving of an infinite Number of Corpuscles which adhere to, or I may add rather, hover about the Earth as the Down does on the Coat of a Quince. *Gravesande* in Book 2. Part 3. Chap. 12. of his mathematical Elements of natural Philosophy tells us, that tho' Air is corporeal and heavy, yet (agreeable to what is before set down on this Head) its Parts yield to any impress'd Force, and are very easily mov'd one against another; that it presses in Proportion to its Height, and that that Pressure is every where equal; it is plain therefore that it ought to be reckon'd amongst the Fluids and admits of the following Definitions.

D E F I N I T I O N I.

ALL that Air with which the Earth is encompass'd, consider'd together, is call'd the Atmosphere of the Earth, or simply the Atmosphere only.

D E F I N I T I O N. II.

THE Height of the Air above the Earth is call'd the Height of the Atmosphere.

THAT Air is a Body appears from its Exclusion or rather resisting all other Bodies, from the Place where it is in its compress'd or contracted State; for tho' it will suffer itself to be compress'd, yet you can't with any Force, force it from any included Place, except you break the Vessel, as is seen in the Piston of a Syringe &c.

THAT it is heavy is prov'd by its pressing upon the Surfaces of other Fluids, and the sustaining them in Tubes, that it yields to any Impression and has its Parts easily mov'd, is also plain.

OF this Atmosphere (or the Air in it) it is generally suppos'd that the supreme Parts are more subtle than the inferior, but it often happens, that the middle Parts are more dense than those which are lowest and nearest the Earth. First, because the lighter Particles seeking the higher Place, they are therefore the more subtle and light. Secondly because those Parts or Particles easily get together in the middle of the Air, and so become thick and heavy, especially when the warm Particles of Air which are car-

* Itaque Atmosphæra & Aer nihil aliud est quam textura multorum Corpusculorum, quæ Telluri adhæret; sicut Lanugo Pomum Cotoneum circumvestit. vid. *Varen.* Geograph. general. Sec. 5. Prop. 3. Pag. 324. of the Elziver Edition.

188 *An Introduction to a General System*

ried up along with them leave or desert them, and the Rays which are refracted from the Earth in that middle Region, have no Force because of this Distance; and from this it comes to pass, that after Rains the middle Air (which as has been before observ'd, is of the same specifick Gravity of Vapour) is more serene (to wit) because the thick and heavy Parts are separated from it.

IT has been a Question held in Debate amongst the Philosophers, *whether the Atmosphere or Altitude of the Air above the Earth, be one and the same in all Places, and whether its Figure be spherical or not?* That it should not be the same, but that there should be different Altitudes in different Places, seems to follow from this, that the Sun is only vertical in one Place and at one Time, and that it shines obliquely, and therefore but faintly in other Places which are nearer its Body, and the polar Influences; and therefore the Power of the Sun's Rays in the Elevation of Vapours is different, and consequently the Vapours themselves are lifted to different Heights; to wit, in Places to which the Sun is vertical, there should be the greatest Height, in the opposite Position the least, and in Places about the Pole they should be midling, even so as that the Figure of the Atmosphere should be ovular; and so does *Cartes* Lib. xiv. by a peculiar Method endeavour to explain.

BUT how specious soever at first Sight this appears to be, it is contrary to Truth (to wit) *that Truth that the Altitude of the Atmosphere is the same in all Places*, and that not only in all Places, but also at every Season of the Year; in the Summer as well as the Winter it remains constantly the same, as whoever will take the Pains may find clearly prov'd by *Varenius* in the 5th Section of his *Geograph. general.* Prop. xiv, xv, xvi. where it is demonstrated that what *Archimedes* has said of Water is also applicable to Air; for that that Part of Air which is less press'd is expell'd by that which is more; every Part therefore of Air is press'd upon by the Air which is above it, which is the Cause why the Figure of the Atmosphere is spherical and not ovular; neither does the Condensation or Rarefaction of Air change its Altitude, because 'tis not the whole Atmosphere which is condens'd or rarified at once, but some Part only, sometimes this, sometimes that, and sometimes the other. The only difference seems to be this, that this Condensation may be greater at one Time than another, but this Difference can encrease its Altitude but little.

AND.

of Hydrostaticks and Hydraulicks. 189

AND as to its being higher in the Summer than the Winter in this Country (because our Air thereby is attenuated and made lighter in one Season than in the other) there is nothing in it; because tho' it be Winter here, it is Summer in other Places, on which Account it is, that Part of our Air is mov'd towards the Air of other Places, where the Air is not so high; and on the contrary whilst the Air of our Country is depress'd by the Cold of our Winter, Part of it moves to those Places where it is then Summer; (to wit) until the whole Air is equidistant from the Center of the Earth.

THE same Reason prevails by Day and Night, for whilst the Air is contracted with us in the Night, it is rarified more in another Place, and so the Air of our Country is mov'd again till it is again brought to a spherical Figure; all which by the by must be the Occasion of the Fluctuation and Restlessness which is in Air, ordain'd as it is by that great Author and Architect of all Beings, whose Works are Wonderful.

THE same Reason also takes Place in Clouds and Rains or Vapours, which are made in this or any other Country; for by these it may be seen that the Altitude of the Air ought to be more or less depress'd; but that I answer, that there is no Time but when it rains in one Place or another, and because it does rain in any one Place, the Air is never the less lightened thereby, as it was not when it rain'd in some other Place, distant from it before; and so the Reason is the same, and the Quantity of Air not encreas'd or diminish'd.

THERE have been † some who have been so curious as to enquire into the exact Altitude of the Atmosphere, as whether it be 5, 10, 20, or 30 Miles more or less, all which is according to the Density of the Air in the different Regions of it, which *Varenus* Lib. 1. Prop. xviii. tells us is of three different Kinds, the middle is colder than the first and third, but that third is chiefly compos'd of the most subtle Air of all, and so is consequently very light and thin. It has been intimated before, that if the Air was equally dense, a Column of it taking up 800 Times the Space as Water does, would reach above four Miles high, but as it is so very thin in the upper Region it is difficult to tell how high the Atmosphere is extended, perhaps 10, 20, 30, or 40 Miles, since Air without the extraordinary Help of Heat may be extended as 14 to 1.

BUT to come nearer the Point in Hand, the Effects that such Mutations of Air and Weather (as has been before mention'd)

† Monsieur Gobart says that the Atmosphere is 37000 Foot high.

has on all hydrostatick Calculations, especially that of the Barometer, Themometer, &c. are very extraordinary, such I mean as are or have not been accounted for.

FOR by the last Instrument, to wit the Thermometer, is plainly shewn (as *Varenius* Prop. 8. Pag. 328. *prædict.* sets down) that it is by the Heat or Temperature of the Air in hot and cold Weather, that we take our Measures from, in which we see that the heavier Air becomes, the less Room Water takes up in the Glass, as also by how much the hotter Air is, the more Room it requires; the true Reason of the different Gravity of Air and its Effects in the Barometer Dr. *Desaguiliers* (in his Notes on *Ozanim's* Hydrostaticks and in other Places) gives in these, or Words to this Purpose.

“ THAT the Vapours do not (as is or has been suppos'd) increase the Gravity of the Air, seems more than probable on this Account; namely, that when the Vapours are in the lower Region of the Air, as in rainy Weather, then the Air is lightest, as appears by the falling of the Spirits in the Barometer &c. And when the Vapours are in the middle Region of the Air, that is, when the Clouds are high, they don't encrease the Pressure of the Air; for altho' the Air be heavier then, it is not because the Clouds are high; but the Clouds are high, because the Air on which they are suspended is heavy; for when the Air near the Earth is more dense than usual, then it becomes heavier than the Vapours which must then ascend, and at last settle in the Regions of the Air, which is of the same Gravity with themselves.

“ IF the Vapours were the Cause of the Encrease of the Air's Gravity, there must be as many Vapours in the Air at a Time, as are equal in Weight to three Inches of Mercury; for so much we find the Mercury rises or falls in the Weather-glass. Now Mercury is about fourteen Times heavier than Water, and consequently there must be in the Air at once as many Vapours, as are equal to a Column of Water of 42 Inches, and whose Base is equal to the Surface of the Earth; and he concludes that the Reason why Air is heavier at one Time than another, arises more probably from there being more Air on that Part of the earthy Surface when the Air grows heavier, and this proceeds from Winds; for Example, if the Wind (which as the Doctor says) is nothing else but a Stream of Air, should blow on any Place, and the Air thus mov'd should be pent in that Place by Mountains or Hills: Or if two contrary Winds should

“ should blow on the same Place, in either Case the Air will
“ be heap’d up in the Middle; and consequently there being more
“ Air its Gravity will encrease; but if the aforesaid Circumstan-
“ ces or the like don’t happen in any particular Country, then
“ the Air which is over it will grow less in Quantity and conse-
“ quently lighter. Whence it is plain, that Winds are the only
“ Causes of the Variation of the Air’s Gravity.

FROM this general Account of Air I proceed to several things which are more particular.

First, that the Superficies of all Fluids are press’d by Air, and in this consists its Gravity (the Subject of the present Chapter). And this among other Experiments, which are and will be produc’d, is found out by the Air-pump; for if you lay your Hand on the Mouth of a small Receiver, and by the Pump draw out the Air, your Hand will swell in the Receiver, and after a few Suctions the Air will press upon your Hand so that you cannot raise it.

Secondly, If you take a drinking Glass and turn it down into Water, the Air being turn’d out or rarified by burning of Paper &c. If the Glass be rais’d perpendicular on its Mouth and put into a Basin or Bowl of Water, the Water within the Glass will ascend higher than the stagnant Water which is in the Basin without, provided the Glass be longer or above that stagnant Water.

UPON these Principles diving Bells are also made, by which Seamen descend into the Sea and fish up Gold and other Goods lost in a Wreck; for in that you may breath freely under Water, yet the farther the Bell sinks the more the Air will be compress’d. When it is about 33 Foot under Water, the Air will be compress’d to half the Space in which it was before; which often breaks the Blood-vessels of those which are therein, and makes them bleed at Mouth, Nose and Eyes.

Thirdly, If you tie a Bladder to the Mouth of a Receiver, and extract the Air; then the internal Air will depress the Bladder so much, that Man’s Strength will not be able to sustain it.

Fourthly, Invert a Receiver, and tie a Weight to the Neck of a Bladder over the Mouth of the Receiver, and hanging on the Outside of it; having driven the Air out of the Receiver, the outward Air will so press on the Bladder, as to thrust it up into the Receiver, and raise the Weight.

Fifthly, Take a Piece of Glass, and put it on the Mouth of a Receiver, having drawn out the Air, and the Weight of the incumbent

cumbent Air will break the Glass; by which it appears that Air presses every Way; and which is also prov'd by the strong Cohæſion there is of two flat Pieces of Glass or Marble exactly polish'd and ground together; as also by a glass Recipient's sticking so close to the Plate after the Exſuction of the Air, that it requires a considerable Weight to repulse it away.

Sixthly, In the *Torricellian* Experiments, if the Tube with the Mercury be put into a long Receiver, the Mercury will fall down at the Exſuction of the Air, and if in the Tube there be left a small Bubble of Air, that Bubble will expand itself and fill the whole Capacity of the Tube, even so as to depress the Surface of the Water, under the Surface of the stagnant Water, and a flavid or yellow Bladder, after the Pressure of the external Air is taken off, dilates itself as far as it can.

Seventhly, The Expansion of the Air in a Bladder, will raise a Weight after the external Air is taken away; and a Bladder in which Weights are put to sink it under Water, will rise with its Weight after the Extraction of the external Air; also a Piece of Cork to which is tyed just so much Weight as to make it sink all under Water, except the Surface of it, after the Air is extracted will rise higher, but when you let in the Air again it will immediately sink towards the Bottom.

Eighthly, A glass Bubble in which is left just so much Water as will sink it, after the Extraction of the external Air will rise; and if you draw out the Air from a square Bottle, the Weight of the incumbent Air will break it to Pieces; also if you put such a Bottle so closely stoppt, that none of the Air can get out of it into the Receiver; after you have drawn out the external Air, that which is in the Bottle will so dilate itself as to break the Bottle.

Ninthly, If you take a glass Bottle half full of Water, having a glass Tube cemented in the Neck of it, one End of which is below the Surface of the Water, and the other being above the Top of the Bottle, has a brass Top with small Holes in it, if you put this into the Receiver and pump out the Air, the Air in the Bottle will dilate itself so, as to press on the Surface of the Water, and raise it up in Spouts through the Holes of the Tube like a Fountain.

Tenthly, I shall only add two other Observations of Dr. *Desaguliers* (and others who have expatiated on Air) which relate to Sound, by which the wonderful Properties of it are plainly discover'd.

of Hydrostaticks and Hydraulicks. 193

IF you put any Animal into the Receiver, and pump out the Air, the Animal, let it be a Toad, a Mouse, Dog, Cat, or whatever else will go thereinto, it will by Degrees languish and in a little Time die; and if you put therein a Bell so rais'd on a wooden Frame, that it may have Room to move into the Receiver, and pump the Air out; then if you shake the Pump so as to move the Bell, you will hear very little Sound from it.

IN the Paragraphs beforegoing are abstracted the wonderful Effects of Air as they discover'd by the Pump, the following are very plain and common Experiments, proving the Gravity of the Air deduc'd from the learned *Gravesande*, Book 2. Part 3. Chap. xii.

EXPERIMENT 1. (*Fig. 1. Tabula seq.*) Take a glass Tube A B, about three Foot long, and about $\frac{1}{4}$ of an Inch Bore; if you stop up the End A, and let the Tube be fill'd with Mercury, and let the other End be immers'd in a Vessel full of Mercury, the Mercury will be sustain'd at the Height of about 29 Inches *English*, or, as *French* Writers say, about 26 or 27 in *Paris* Measure; for the *French* Foot exceeds ours. This Rise is occasion'd by the Pressure of the Air on the Surface of the Mercury in the Vessel, which cannot press equally in every Part of it, unless in the Tube where no Air is, there be a Column of Mercury which presses equally with outward Air.

EXPERIMENT 2. (*Fig. 1. Tab. seq.*) That this Pressure may not be chang'd when the Tube is inclin'd, it is requir'd that the Mercury should keep the same perpendicular Height. If therefore there be two Vessels containing Mercury, in which Tubes in the Manner abovemention'd are immers'd, of which E D is inclin'd to the Horizon, the Mercury is sustain'd at the Heights *b f* and *i g*, so that *f* and *g* are in the same horizontal Lines; supposing the Surfaces of the Mercury in the Vessels to lie in the same Plane.

EXPERIMENT 3. (*Fig. 2. Tab. seq.*) The same Pressure of Air sustains the Water in the glass V. which is immerg'd in Water and fill'd with it, and then is pull'd out all but the Orifice which still remains immers'd. And in the same Manner Water will be sustain'd, even to the Height of 32 or 33 Foot; for Mercury or Quicksilver being 14 Times heavier than Water, a Pillar of Water a little more than 32 Foot high presses equally with a Column of Mercury 29 Inches high, which Pressure is equal to the Pressure of the Atmosphere.

To determine then the Height of this Atmosphere, or, in other Words, to know how high a Column of Air must be that is equal to 28

194 *An Introduction to a General System*

or 29 Inches of Mercury, or 32 or 33 Foot of Water; we must suppose as it is indeed found by Experiments, that Air is to Water as 800 to 1: Supposing then that the Density of the Air was equally the same from the Top to the Bottom of the said supposed Pillar, then the Height of the Atmosphere would be 25600 Foot; but as the higher or upper Part of the Air is supposed to be lighter, or in other Words more rarified, than the lower Air is which is thicker and denser, and as ordinary rarified Air to common Air is, by *Marriotte*, said to be as 16 to 4, the Height of the Atmosphere, if you add them together and take the Medium, must be 256000 which is about 4 Miles $\frac{3}{4}$; † tho' Monsieur *Gobart* says, it is 37000 Foot high, which is above 7 Miles.

BUT whatever it be, it is on this Calculation of the Air's Pressure that depends all the Rules for raising Water by Pumps or other Engines, and that that which was heretofore call'd by the hard Names of Attraction, *Fuga Vacui*, and other Appellations, is really no other than Pulsion or the exterior Pressure of Air.

TO proceed, *the Pressure of the Air depends upon its Height*, as may be easily deduc'd from what has been said; but it is more immediately prov'd by carrying the Tube with the Mercury beforemention'd to any high Place; for when you carry this Machine up a Hill, for every 100 Foot you rise (as says *Gravesande*) perpendicularly, the Mercury descends a Quarter of an Inch: And *Marriotte* in his Discourse, on the Equilibrium of Fluids, says, that if you carry a Barometer up to the Top of a Mountain or a very high Tower (how high he does not say) the Mercury will fall by little and little, till it comes to 24 or 25 Inches; and if you go down into a Cave or Mine, it rises by little and little according as you descend, being successively press'd by a greater Quantity of Air.

That Air presses equally every Way, appears from this, that this Pressure is sustain'd by soft Bodies, without any Change of Figure, and by brittle Bodies without breaking; tho' this Pressure be equal to the Pressure of a Pillar of Mercury of 29 Inches, or a Pillar of Water of 32 Foot; any Body may see that nothing can preserve those Bodies unchang'd, for the Pressure on all Parts is equal; but it is plain that the Air does press in that Manner; for if you take away the Air on one Side, the Pressure

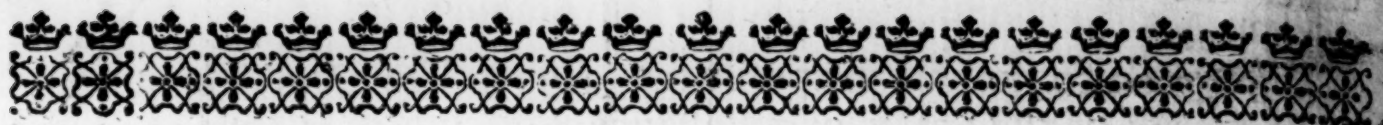
† Columna Aeris perpendicularis extenditur ad Altitudinem 37000 Pedum, collateralis extenditur ultra 10000. vid. *Paragraph. 2. Pag. 76. Philosoph. Tract. de Barometro.*

of Hydrostaticks and Hydraulicks. 195

is sensible on that which is opposite to it, as has been demonstrated under the Head of Hydrostaticks, but is made more plain in this Place.

To go on to the last Experiment (*Fig. 3. Tab. seq.*) Hang a glass Tube to one of the Scales of a Ballance A B, which is shut at D, and three Foot long; fill this Tube with Mercury, and let the End E be immers'd in the Mercury that is contain'd in the Vessel V; the Mercury by the Air's Pressure is sustain'd at the Height *f* in the Tube, and the upper Part of the Tube F D is left void of Air to make an Equilibrium: You must put into the opposite Scale a Weight equal to the Tube and the Mercury contain'd in it; the Mercury in the Tube cannot press the Ballance, for its Action against the Sides of the Tube is horizontal; but the Air acts upon the upper Part of the Tube, and the Column that is sustain'd by the Tube is equiponderate with the Mercury that is contain'd in the Tube: If letting the Mercury run out, you suffer the Air to come in, then nothing but the Tube weighs down the Scale; which proves that the Action against the inferior Surface of the upper Part of the Tube destroys the Action on the exterior Surface, and that the Air presses upwards and downwards with the same Force; and by this Experiment also is confirm'd what has been said of the Air's Gravity; and thus far by ordinary and common Experiments in glass Tubes, from whence also are calculated several Instruments whereby the Gravity of the Air is so sensibly distinguish'd, as that it foretells Change of Weather and the like, to which Use the *Torricellian* Experiment is chiefly apply'd. But this I shall reserve for the next Chapter.

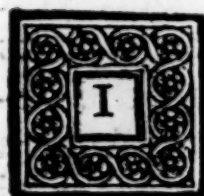




B O O K. II.

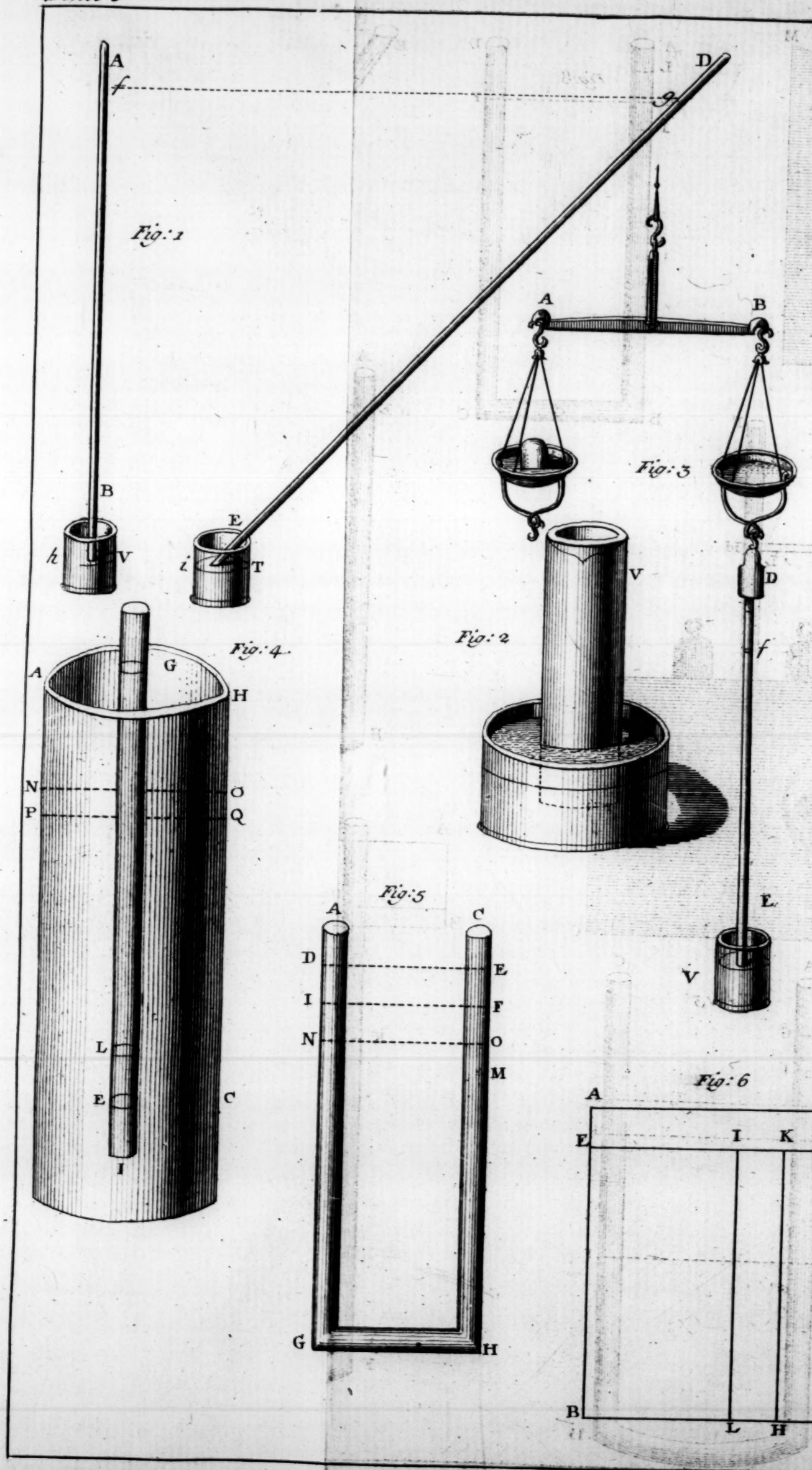
C H A P. XV.

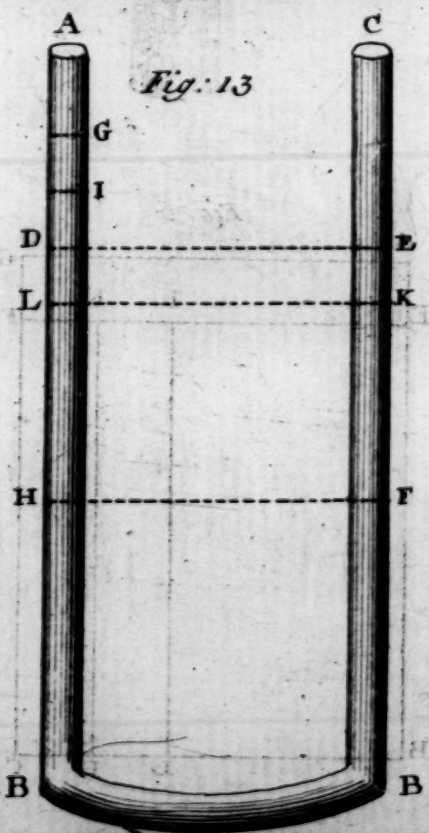
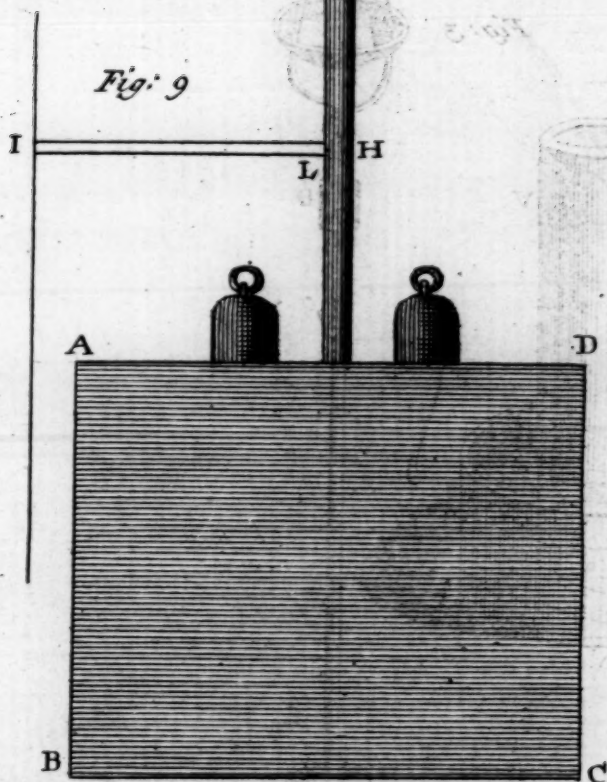
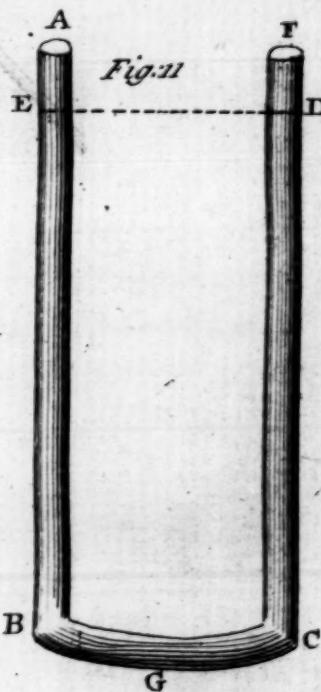
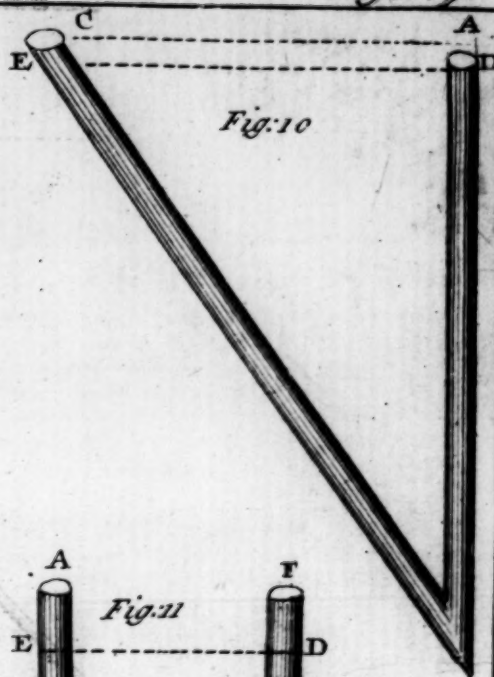
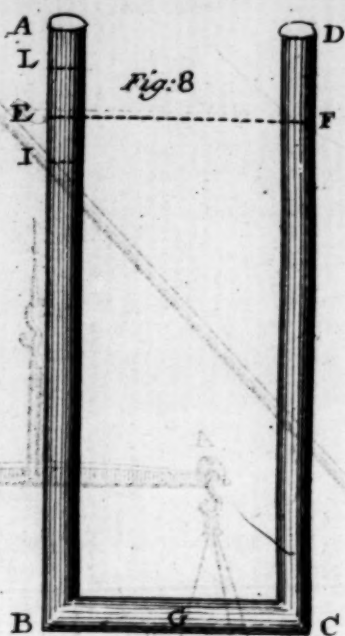
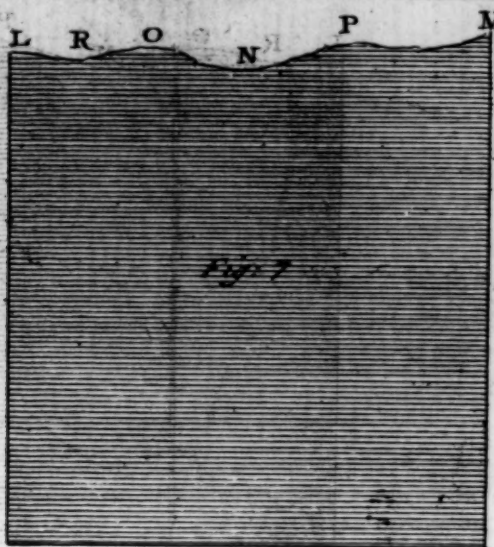
Of several Instruments whereby the Principles of Hydrostaticks are more fully explain'd.



It has been already intimated, that what has been said in the foregoing Chapter of Mercury or Quicksilver, holds true likewise in respect of other Fluids. On which Account it is that I shall, for the farther Illustration of this Subject, produce in this Chapter all, or most of those Instruments by which the Principles of Hydrostaticks are explain'd.

It is then obvious (*Fig. 12. Tab. seq.*) that the Air being suck'd out of the Siphon, through which Wine and other Liquors are decanted (as *Wallis Prop. xv. Fig. 321.* of his *Mechanicks* sets down) at E the Wine or other Liquor in the Vessel, A B F G will be thrust up by the Pressure of the Air upon the Surface A B, into the other End H of the Siphon apply'd to the said Surface, and the Wine will be thrust upwards in the Siphon, till the Weight thereof comes to an Equilibrium with the Pressure of the external Air, suppose till it comes to the Height C I. If therefore the Top D of the Siphon be not higher than I, the Wine will rise to the said Top of it, and there finding a Vent or Passage down the other Leg of the Siphon D E, it will go that Way, and so run out at E; continuing so to do, (the Causes still continuing) till the Vessel is emptied. But it is to be observ'd, that the Mouth E of the Siphon must be lower than the Mouth H; for else E and H being equally press'd by the Atmosphere, if the Leg D E be but of an equal Length with D H, and consequently the Fluid in one Leg of equal Gravity with the Fluid in the other; the Fluid would stay in the





the Siphon, not moving one Way or the other, without some external Force besides the Air. And by Parity of Reason, If D E be shorter than D H, the Fluid would run (not from H to E, but) from E to H, the Air coming up at E, and thrusting the Fluid forward the contrary Way. This would certainly happen, except at least the Siphon be so wide, as that the Air may ascend by the Sides of the Fluid, while the Fluid itself descends in D E.

I might in this Place give a more particular Description of the Siphon and its Uses and Improvements, but that I have in the Books wherein I have treated of Hydraulicks appropriated a Chapter entirely to that Purpose; on which Account I shall not enlarge upon it here, but only observe, that by this it is the Notion of a *Vacuum* is destroy'd, tho' some of the Ancients endeavour'd to establish it hereby; for that this so much contend'd for Opinion, which is sometimes also call'd *Fuga vacui*, is no other than that by the Exsuction of the Air at E, the Water ascending contrary to its own natural Propension to I, by the external Pressure of Air; tho' even then it is certain it will not rise to above 33 or 34 Foot at most; but of that more in its proper Place.

THE same thing happens in the Pump (*Fig. 13. Tab. seq.*) where if the Height C D were greater or not lesser than C I, which happens by the Pressure of the external Air, the Water would not ascend through D, neither would C be press'd any farther than the other Parts of the Superficies A C B, and the whole Labour of the Pump would be in vain and of no Effect: But if D be below I, the Water will ascend through D even to I, if there be no Stoppage or Hindrance even up to the Handle if it be not higher than I; and if you move again the Handle it will overtop F and G, and rise even to I; yet so that if the Handle is let down again, the Water will subsist at I, whilst there is more coming up through F and G, the Valve G being shut at the Depressure of the Rod or Piston, and then the Water will run out with great Violence at H.

MUCH more might be said under this Head, to demonstrate that this whole Process is effected by the Pressure of external Air, but that I shall have Occasion to mention it so often in other Places; but I can't but note (before I quit this Part of my Chapter) an Error that *Wallis* himself, and after him the learned Dr. *Wells* Rector of *Cotesbatch in Leicestershire*, lately deceas'd, are guilty of, when they affirm that such Wells as have their Water lying very deep, can't have it rais'd by a Pump, but
by

198 *An Introduction to a General System*

by a Bucket and Rope; because, say they, according to these Principles of Hydrostaticks, the Distance between the Water at C in the Well and the Valve E (or Bottom of the Sucker when at the lowest, *viz.* at E) must not be greater than the Altitude, whereto the Pressure of the Air is sufficient to make the Water rise, which is found by Experience to be about 33 Foot.

AND *Wallis* * expressly tells us in Pag. 746. of his *Mechanicks*, that Water can't either by a Siphon, Pump, Syringe or any other Instrument whatever, (for the same Reason holds good in all) be rais'd above 33 or 34 Foot; when on the contrary we have Pumps that raise Water commonly 50, 60, 70 or 80 Foot, and Mr. *Fowle* and Company have one that will raise it 120, as may be seen in their printed Papers; tho' all the while it must be own'd, that the external Pressure of the Air will not rise it to above 33 or 34 Foot, which suppose to be F G; nor do our Pump-makers ever fix that Valve or Clack at above 25 Foot high above the Water; but then a long Rod or Piston of 50, 60, 70, or 80 Foot may be added, which will by the Repetition of the Stroke and by the shutting of the Valves at G and E, mount the Water to almost any Height, the Water ascending by the Sides or through the middle of the Bucket or Sucker all the while. But how this is done, will be more particularly set down when we come to the Practice of Pumps.

BUT to resume our Subject from which this last Observation has been a kind of a Digression, Dr. *Desaguiliers* Prop. xix. Pag. 121. of his Lectures on experimental Philosophy says, that the Ascent of Water, even in a Syringe, arises also from the Pressure of external Air, (*viz.*) when the Tube of a Syringe is immers'd in Water at *q*, (*vid. Fig. 14. Tab. seq.*) the Piston being brought to R S, is left void of Air, so that the Gravity of the external Air pressing upon the Superficies *o p*, will make the Water ascend in the Tube as high as R S, (*viz.*) that the Part of the Superficies of the stagnant Water at *q*, may be press'd by the incumbent Water in the Syringe with the same Force, as the Superficies *o p* is press'd by the incumbent Air.

THE same Effects happen by the Help of the *Æoliple*, the Invention of Father *Mersennus*, as the aforesaid *Wallis* mentions

* Hinc est quod Hydrargyrum non possit Siphone, antliâ, Syringâ (nam & illis eadem est Ratio) aliove Suctionis organo quocunque ultra Pedis Uncias 29 in altum trahi, nec Aqua, ultra Pedes 33 aut 34 circiter, aliaque Fluida pro suâ cujusque Gravitatis Ratione &c. Vid. *Wallis* Prop. xv. Cap. xiv. Pag. 746. of his *Mechanicks*.

of Hydrostaticks and Hydraulicks. 199

Pag. 736. predict. which Dr. *Desaguiliers* *Pag. 119. Prop. xviii* explains in the following Manner.

WHEN a Man (says he) by the Muscles of his Breast enlarges the Cavity of the Thorax, then the external Air finding Room wherein to expand itself, rushes in at his Mouth into his Lungs; so that if one Orifice of a Cube be in his Mouth, and the other immers'd in Water, then that Part of the Superficies of the Water, which is under the Tube, is free from Pressure; and since the other Parts of the Water are press'd by the super-incumbent Air, so that the Superficies of the Water is press'd by the super-incumbent Weight of the external Air, it must needs be that the Water will ascend up the Tube, to wit, that the Parts under the Tube may be equally press'd by the incumbent Water, as much as the rest of the Superficies of the Water is press'd by the incumbent Air; so that the Pressure of the external Air upon the Superficies of the rest of the Water, is the Cause that the Water ascends up the Tube. *Vid. Fig. 16. Tab. seq.*

ANOTHER Experiment this curious Gentleman makes use of (for which see *Pag. 120. Plate the 6th. Fig. 15.*) is to take a Glass with a narrow Neck, but without any Bottom as C, put a Tube in its Neck at B and cement them; then tie a Lamb's Bladder to the End of the Tube within the Glass, and a large Ox-bladder D over the open End of the Glass, so that the Bladder may be forc'd inwards, and drawn outwards; you will observe all the Air within the Lamb's Bladder wherein the Tube is inserted will be expell'd; if you draw the Ox-bladder outwards, the Air will rush again into the Lamb's Bladder; after this Manner Respiration is perform'd, the Air in the Cavity of the Thorax acts on the Lungs, just as the Air in the Ox-bladder does on that of the Lamb's. If the open End of the Tube be immers'd in Water, and the Ox-bladder drawn back, the Water will ascend the Tube and fill the Lamb's Bladder, as *vid. Fig. 15. Tab. seq.*

THIS Ubiquity and Pressure of Air is also visible in a drinking Glass, which if you take and immerge it in Water, so that the Air can't get out, the Cavity will not be fill'd, the Air within hindering the Ascent of the Water; which (as that learned Gentleman observes) may be shewn by putting of Paper into the Bottom of the Glass, which will not be wet; but if you set the Paper on fire, the Air will be so rarified, that the Water will rise a good Way into the Glass.

UPON

UPON this Principle it is also, that diving Bells are made, by which Divers descend to the Bottom of the Sea, to fetch up Money or other valuable Goods that are lost there, where they breath very freely under Water, and as I have been told, drink Punch and are very merry; but when it is about 33 Foot under Water, the Air will be compress'd to half the Space which it was before; and this sometimes breaks their Blood-vessels, and makes them bleed at Mouth, Nose, and Eyes. And upon this Principle also Cupping is explain'd; the internal Air in the Blood rarifies, when the Pressure of the external Air is taken away, and distends the Skin, and makes it swell in the Glass. This is a Proof says my oft quoted Author, whom I can never enough commend, that there is a great deal of Air in the Blood.

BUT to proceed to a farther Demonstration of this Principle of Gravitation, the Barometer or Weather-glass is a more ample and clearer Proof of the Gravitation of Fluids one upon another, than any Instrument yet produc'd, in as much as thereby the Weight and Measure of them is found out.

THIS useful Instrument is, as some learned Men observe, so call'd from βαρὺς signifying Weight and μέτρον a Measure, (being as is elsewhere hinted) the Measure and Weight of Air; because the Mercury or Quicksilver rises and falls in Proportion in the Tube, as the Air is heavier or lighter, and so more or less presses the Quicksilver, that is in the Well, as they call it, of the Barometer; and thus far is agreed by all: But what it is that causes the Air to become sometimes heavier and sometimes lighter, is not so agreed.

BUT to proceed to the farther Explanation of this useful Instrument, it may not be amiss to take a View of what the famous Jesuit *Gobart* in a philosophical Tract of his, concerning the Barometer Pag. 2. has set down concerning the Ascent and Descent of Fluids, as it is in Question 1. Pag. 2. wherein the Cause of the Ascension and Descension of Mercury in the Barometer is very succinctly handled, which I the rather give because he was a Plenist, and maintain'd *that Nature does not admit of a Vacuum?* for says he, God Almighty has so dispos'd of Nature, that where one Body deserts any Place, another succeeds, and therefore Nature does not admit of a *Vacuum*.

IN the next Place he says, *that Nature does not abhor a Vacuum*, because she can't abhor that which is not, and of which there can be no Danger; and in the next Place he says, that the Ascent of Mercury and other Fluids does not arise from the Dread

Dread or Fear of a *Vacuum*; for if Mercury was to rise in a Tube from the Dread of that *Inane*, it would not stop at the Height of 30 or 40 Inches, but this Fear would urge it on, until it had driven it to 40 or 50 Foot high, and so on.

THE Barometer, this ingenious Gentleman chiefly recommends, is very much like that which *Ozanam* in his Hydrostaticks gives a Description of, which he calls Mr. *Hugen's* Barometer, which take as follows.

LET A B C be a glass Tube, hermetically seal'd at one of its Ends A, and open at its other End C, that as much Mercury may be pour'd into B, as will fill the Tube which reaches from the middle of the cylindrick Box E, to the middle of the other D, which must be 27 Inches distant from the first E; because a Pillar of Air reaching from the Earth to the Top of the Atmosphere or utmost Surface of the Air, will keep 27 or 28 Inches of Quicksilver in Equilibrio in a perpendicular Tube: Then fill C E the remaining Part of the Tube with any other Liquor, which will neither freeze in Winter nor dissolve the Quicksilver, as suppose common Water mixt with one sixth of *Aqua Fortis*.

WHEN the Mercury descends one Inch, (*per* Example) in the Box E, by the Gravity of the Air, it will rise as high in the Box D, and the Water which is in the remaining Part of the Tube C E will descend in the Box E, and if (again) the Cavity of that Tube be 15 Times greater than that of the remaining Part of the Tube C E, 15 Inches of the Water of this narrow Tube, will be requir'd to take up the Height of one Inch in the Box; therefore as often as the Mercury rises or falls one Inch, the Water will rise or fall 15 Inches; and likewise when the Mercury rises or falls one Line, the Water will fall 15 Lines; so that this Barometer shews the Alterations of the Air's Gravity 15 Times more sensibly than any common one. But *D Desaguiliers* Pag. 140 of his System of experimental Philosophy says, that "this Sort of Barometer has one Inconvenience, "which is, that as the Weather is hot or cold, so the Liquor "in the Tube C E will dilate or contract itself, and consequently "rise or fall; whereas the Mercury continues still the same "Height. Since therefore the Mercury keeps always at the "same Height, however the Tube be inclin'd; the best Contrivance for a Barometer seems to be this, (*vid* Fig. 21. Tab. *seq.*) let A B C be a Tube bended as in the Figure, let B C "be about 26 Inches long, and A B so inclin'd, that it may be "15 Inches; whereas A E should not be above five according
D d to

“ to the Structure; so for every Inch the Mercury rises in the
 “ Tube, it will rise three in the inclin’d one A B.

VERY much has been said by Authors of the natural Effects of Air, in this remarkable Part of Nature; (the famous Jesuit *Gobart* in *Tract. Philosoph. de Barometro* Quest. 2. Pag. 133. & *seq.* says) that this Ascension and Descension of Mercury, is owing to the different Ponderosity and Mutation of Air, but that that Mutation in Air can’t come to pass until other Changes shall go before, and which shall accompany, and be subsequent to that Mutation; even as there can be no Expression of Water out of Linnen, unless Water was therein before, with more to the same Purpose; and then concludes *Pag.* 135. that ’tis a condensative Cold, which is a positive concurrent Cause to the greater Weight of Air; and that the Expression of Vapour is its Concomitant (only by the Accident *Condensation*) for Serenity is a necessary Consequent to that Condensation and Expression of Vapours; for as the Generation of one, is the Dissolution of the other; so from the Vapours which are so express’d from Air, and (which are future Materials for Rain) follows that Serenity of Air, which is always consequent to it.

IN the last Chapter, I gave from Dr. *Desaguiliers* a very short and plain Account, of the Ascent and Descent of Mercury in the Barometer &c. I shall finish what I began in that Chapter, from the Observations of our oft quoted learned Jesuit abovemention’d, who concludes his Book with all the Observations and Objections which seem possible to be made on this great Phenomenon of Nature.

HE lays it down as a Maxim in Hydrostaticks, that Air may be either rarified or condens’d; that by Rarefaction the Weight of Air is diminish’d, because of the Multiplicity of Pores that are therein; even as Pumice-stones, Sponges, or other opacous Bodies, are lighter than those which are of a closer Contexture: He concludes therefore that condens’d Air presses and elevates the Mercury in the Tube, more than rarified Air does, because by Condensation, the Weight and Elaterium of the Air is increas’d; for condens’d Air is so constituted, that the superior Parts act upon the inferior, by their Pressure; and that the Cause of the Accession of superior Particles, upon those which are inferior, is a condensative Cold; and in another Place tells us, that Rarefaction which is caus’d by Heat, is that by which Air or any other Fluid extends itself from the Center towards the Circumference; but Condensation (which is a heavy Quality) causes the

of Hydrostaticks and Hydraulicks. 203

the Parts, of which it is compos'd, to recede from the Circumference to the Center.

Now these things being so, it is obvious (to common Observation) that the Air is heaviest and exerts its lateral Pressure on the Barometer most, when it is the most condens'd; he compares this elementary Sphere to a large Vessel, which he supposes to be fill'd with Sponge, (explain'd by its own natural Dilatation) and on which Water is pour'd in such a Manner, that there is no Part within the Vessel where there is not Water and Sponge mixt together; by the Sponge he would represent common Air, the Earth, and other sensible Bodies; but by the Water the Æther or Atmosphere, and as it is in the Vessel which is every where fill'd with Water or Sponge; so it is in this elementary Sphere, there being in every sensible Place Air, or some other Body, and Æther also.

Now the Ponderosity or Weight of this Air is encreas'd from divers Causes, one whereof is the * blowing of the North and North West Winds, which are more condens'd by Cold than the other Winds are; and these Winds meeting with others that rise from other Parts, at the same Time; gather together on a Heap, and mix with common rarified Air, and so encrease the Gravity of the Atmosphere; and tho' there is not always the same Disposition to Rain supposing the Air be rarified, because in the Summer when the Earth is dry, it does not supply Vapours requisite for such Purposes; from whence (regularly speaking) it does and ought to rain less at that Time than either in the Spring or Autumn: In the Winter also, whilst the Earth, and a great Part of the Sea, is constring'd by Frost; few Vapours being

* Not that I esteem the hard blowing of any Winds to be the Occasion of the Ponderosity of the Air, but on the contrary, that it is thereby made the lighter, which is visible by the Barometer in all high Winds, the Congregation of heavy Air together, is generally more leisurely; for Air that is much agitated loses of its direct Gravity, as is evident in a Charriot or other Carriage which is drawn on swiftly, where it is evident, that it cuts less into the Ground than if it was drawn slowly; for which take Gobart in his own Words. *Quia Aer multum agitato multum perdit suæ Gravitationis, secundum Lineam rectam: Nam Ratione Agitationis, pondus tendit deorsum quidem, secundum Lineam rectam; sed tendit etiam secundum obliquam; minus autem illud Corpus ponderat, quod oblique & directe simul tendit in Centrum suum; quia sic dividitur aliquo modo pondus eo quod feratur recta & obliqua Linea in Centrum, ita dividitur suo modo illius Gravitatio: Illud evidens est in curru vehementer tracto; minus enim Terram premit in tali motu, quam silente traheretur. Vid Tract. philosoph. de Barometro. Dub. iv. pag. 178.*

detach'd there from; neither has the Sun Heat enough to draw them to itself at that Time; yet in these Seasons (different as they are) Rains often fall, the Winds abovemention'd wafting them from other Regions, where they were before generated, to the Place where by the Opposition of other Winds, they are forc'd to stop and fall down; so that Winds are both the Forerunners as well as concurrent Causes, of Rain and other Changes of Weather.

LAST of all in the greatest Heats of Summer whilst the Dog-star or Leo reigns (whilst there are not Rains enough to nourish the Corn) there are observ'd, great Commotions of the Winds, frequent Thundrings and often great Showers, all which are foretold by the Barometer, even whilst the Air is in that Disposition; and the Reason why neither some contiguous Parts nor the whole Atmosphere are not agitated or mov'd at the same Time is this, (*viz.*) for that the first Foot of Motion, in the Air, is resisted by the second; which always encreases till it comes to the last Point, in which that Impetus desists, which by how much the greater it is, by so much greater is the Agitation it makes in the Air, all which is nevertheless limited; for a Voice which is sounded in the Air is heard but at a small Distance; even so also a Cannon, on its first Explosion, vehemently moves the neighbouring Air, and is yet nevertheless not heard above ten Leagues, except the Air be very still; and unless it has some farther Helps, to make its Noise perceiv'd the farther; and this is the Reason why all Changes of Weather are circumscrib'd to, and found in different Places.

FROM all which it is inferr'd, that from the Ascent of Mercury is found out the Gravity of the Air; and this Knowledge may be said to be directly and immediate; for as the Depression of one Scale in any Ballance is known directly and immediately by the Rise of the other, (because they constitute one artificial Being) so in like Manner the Weight of Air and Mercury constitute or belong to one and the same thing, and the direct Cognition or Knowledge of the Elevation of one, is also the direct Knowledge of the Depression of the other.

MANY are the Scholiums with which this learned Author fills his Writings, concerning the direct and indirect, immediate and precise Changes of Air, which tend to no more than what (I have I think before laid down) that there can be no Change in Air unless there be such a Ponderosity preceding or going before it (as has been just now describ'd) from whence

(he says) the Ascent of Mercury shews indirectly, (that is, that the Condensation of Air, the Expression of Vapours, and the future Serenity of Weather, are not immediate or momentary) but necessary consequents of this Change; but all these school Definitions which are calculated rather to puzzle than instruct Mankind, I leave to the Discussion of those who have more Leisure than I have; and to sum up all that can be said on this Head, those Vapours which fluctuate in the Air, and which are seen in or before wet foggy Weather, doe not encrease its Gravity; for when they are descending and hovering about the Earth (as they then are) 'tis then the Air is lightest and the Mercury in the Glass will rise the least, and when they are in the middle Region of the Air, they do not encrease its Gravity; for tho' the Air be heavier then, it is not because the Clouds are high, but the Clouds are high, because they are suspended by Air which is heavy, as one Fluid which is heavy, is well known to sustain another, which is lighter; for when the Air is more heavy than Vapours, they are forced to ascend, till they meet with Air of the same specific Gravity of itself; and so continue to subside till the Warmth or Rarefaction of the lower Air gives them Liberty to redescend; so that the Gravity of the Air consists, in that which is condens'd and congregated together, as it is before all rainy falling Weather, which is what was to be prov'd.

A Thermometer is a long Tube of Glass seal'd hermetically, which has a small Bubble at Top as O, and under it a long Neck as at B, which being fill'd about half Way with Spirit of Wine or any other Liquor that does not freeze in Winter (usually ting'd of some Colour to distinguish it in the Tube) serves to shew the Degrees of Heat and Cold in the outward Air.

For this Purpose the whole Length of the Tube is divided into eight equal Parts, and those eight into eight more, to have in all eight Times eight, which is 64 Degrees, to know more sensibly the Change which happens at any Time in the Temper of the Air, observing to what Degree the Water rises that Hour of the Day, according as the Heat of the outward Air is encreas'd or diminish'd; for when the Air is hot, it causes the Air and Ball in the Tube A B to be rarified, and that Air being rarified expands itself and causes the Water to descend: And on the contrary, when the Air is cold it is condens'd, and gives Room to the Water to rise, to which it must be added, that the small End of this Thermometer be open, and immerg'd in an open Vessel with the same Liquor with that which it contains.

THE

206 *An Introduction to a General System*

THE famous Monsieur *Gobart* in his philosophical Tract concerning the Barometer &c. says, that the Thermometer has its Name from θερμὸν which signifies Heat and μέτρον Measure, and that it is made two Ways; the first of Water, and the second of Spirits of Wine. A Thermometer which is made with Water is compos'd of two Parts, to wit, a Vessel and an oblong Tube with a Ball at Top, the extream Part of the open Tube must be immerg'd in stagnate Water, the Water being put into the Tube, it will ascend up to the Middle whilst the Cold encreases, but will descend whilst the Heat encreases; a Sketch of which may be seen as I have taken it from *Gobart's* drawing itself, and express'd *Fig. 15. Tab. seq.*

HIS Thermometer, which is made of Spirits of Wine, is made of one Glas only, where the Ball is not at Top, but at the Bottom (as *vid. Fig. 16. Tab. seq.*) the Ball and above half the Tube are fill'd with Spirits, and the remaining Space is left for common Air; then it is hermetically seal'd, and in like Manner the Parts are noted upon the Frame, to which the Tube is fastned; and whilst the Heat increases, the Spirits of Wine rise; but when it is inclinable to Cold they descend. The Tube may be extended to three or four Foot high, the Divisions may be discretionary according to the Length and Breadth of the Ball, the Tube may be denser or thicker, but the Ball may be smaller, from whence the Spirits will be more capable of Alteration.

THE Barometer and Thermometer differ in the Uses they are apply'd to; the Thermometer is us'd to know the Heat and Cold of the Air, but the Barometer to the knowing the Weight and Serenity of it; likewise the Water of the Thermometer ascends directly, but the Weight or Pressure of external Air indirectly, by the Contraction and Condensation of that which is within.

WITH this Instrument (useful as it is in all green Houses and Stoves) may be compar'd the greatest Heat of one Summer with the greatest Heat of another, or the greatest Cold of one Winter with the greatest Cold of another; and from this you may know which of two Rooms is the hottest, that being the hottest where the Water will descend the lowest in the Thermometer, the least Heat being able to rarify the Air contain'd in the Tube A B, as may be found by Experience; for if * the Hand be laid on the Ball A, its Heat will immediately rarify the Air and Cause the

* Manus applicatus extremo Tubi aerem rarefacit, & illi condensat spiritus intra bullam, --- applicatus bullæ spiritus rarefacit, & illi per suam dilatationem, et aerem comprimunt in summo Tubi. Pag. 56. *Gobart de Barometro.*

Water to descend, which will creep up gently into its Place again as soon as the Hand is remov'd, which will be more easily seen if you warm the Ball by breathing upon it.

I shall conclude this Account of hydrostatick Instruments when I have observ'd, that 'tis by this Thermometer that you may keep your forcing Frames for Melons and other Fruits, to such a due regular and temperate Heat as the Nature of your Plants require; as you may also the true State of Air necessary for the Preservation of those Exoticks which come from different Places beyond Sea, to which End I have, in the House where I now live, a Thermometer, with the different Latitudes of the most remarkable Places of the World alphabetically digested, which may serve as a perfect Scale of Nature in the Direction of what Heat is proper for the Nourishment of every particular Kind of Plant, which ends what I have to say of the Thermometer.

AND before I quit this Account of the Instruments by which the Principles of Hydrostaticks are explain'd, it will not be improper for me to take Notice of the Hygrometer; a Specimen of which we have lately had in the Toy wherein the Man comes out of Doors in wet Weather and the Woman in dry.

THIS Hygrometer which is also call'd Hygroscope, was as Monsieur Gobart Pag. 92. de Tract. philosoph. de Barometro, tells us, not long ago invented by Father Magnanenus of the Society of Jesus; tho' there are others which give an Account of its being the Invention of an Englishman, the Use whereof is to find out precisely the Humidity and Siccity of the Air: Let there be a Chord made of any musical Instrument of Parchment, a Rope-string or bearded Ear of Corn &c. the efficient Causes of which, are the Vapours of Water, which insinuate themselves into the Pores of all opacous Bodies, and because they variously twist and swell the Fibres of other Bodies, so they cause various Motions therein, and the formal Cause is the Recontortion or Retwisting of those Fibres, situated in that various Habitude of Particles, to its first Position again, even so, that if a twisted Chord be turn'd from the left to the right Hand in dry Weather, it will forthwith return from the right to the left in wet.

THERE are several Kinds, but the following one is in Esteem; Make a Common Ballance as (A B Fig. 17. Tab. seq.) which must be suspended by its Center of Motion G, and put into one of the Scales as D a Weight of Lead, and in the other Scale as C, a Piece of Sponge big enough to keep it in Equilibrio; then it will happen that when the Weather is moist, the Sponge grow-
ing

ing moist, by the sucking in of those Particles of Water that swim in the Air (which it will do more easily if it has been first dipp'd in salt Water;) for tho' the Water may be dried, yet those saline Particles which are left behind will render it more susceptible of the Moisture of the Air) will become heavier than the Lead, and cause its Scale to preponderate, and also the Examen of the Ballance which is moveable about the fix'd Point G, to change its Position.

ON the contrary, when the Sponge is dried, by the Dryness of the Air, it will not be so heavy as the Lead, and consequently rise with its Scale, and make the Examen also to turn the other Way, and point to the Degrees of Dryness mark'd upon the Circumference of the Circle describ'd about the Center of Motion G; but instead of an Examen and Circle, you may fasten the Scale C a little Chain made of several little Balls, which fall upon the horizontal Plain as E F, and will lie upon it in greater number when the Moistness of the Air is greater; for in such a Case the Scale C will descend lower, because the Sponge being moister will consequently be heavier.

ANOTHER Kind is thus made, let there be a Box divided into twelve Parts, and those again into 20 smaller Divisions (*vid Fig. 22. Tab. seq.*) in the middle of which let there be also put a Ear of Corn perfectly ripe, to which let there be fix'd a small Index which may distinguish the Degrees on the Box by the Motion of the Ear of Corn. Concerning this Hygrometer divers things are noted; first of all, the Ear of Corn should be mov'd from the East to the West, through the Meridian in wet Weather, but in dry, from the East to the West by the North Pole; the Reason of which is discoverable from the Structure of the Ear of Corn. In the next Place, if you set the Hygrometer near the Fire, the Blade of Corn will turn itself round and round as it were in Dances, either more or less according as it is nearer or farther off.

AND to this Principle may be ascrib'd the Interchanges the Man and Woman make in the new publish'd Toy beforemention'd, as whoever takes a little Notice may be more fully satisfied. There is another Method that † Monsieur Gobart takes in making this Hygrometer, the Draft of which I have taken from his Book *de Barometro* beforemention'd (*vid. Fig. 23. Tab. seq.*) tie

† Et per hos eosdem Vapores multa hæc Oracula loquuntur & enarrant præsentem Aure Statum. Vid. Gobart Tract. philosoph. *de Barometro* Pag. 98. & seq.

(says

(says he) a Rope to a Beam, in the extream Part of which, fix a Weight proportionable to the Rope, (that is) something bigger, and the Weight shall be elevated in moist Weather and depress'd in dry.

IF you desire such a thing in a small Compass, you may use a Piece of Parchment, or the String of a Violin fix'd to the Wall; let the Globe or Ball be beneath, and let the Description of the Degrees be made in Paper or Wood, and if there should be describ'd in a large Circle as at A, and on a pendulous Rope as at B, there will be a double Notation of that Motion (*viz.*) circular and perpendicular, and so both wet and dry may also be known.

THE same is done by a Cat's Gut or other Piece of String nail'd across any Part of a Wall, just in the Middle of the Degrees, but this String should be dipp'd first of all, in salt Water, that it may be the more susceptible of Moisture, and may the sooner retract or shrink up again. And our famous *Jesuit* tells us, that every one unknowingly carries a Hygrometer about with him, if he will observe how his very Hair is let down, in moist Weather, but curl'd in dry; any Part made of Wood, as Doors, Windows, and such like, swell in wet Weather, and shrink in dry, by the Insinuation and Expression of those Vapours beforemention'd, and by those very same Vapours it is, that those dumb Oracles (if I may use *Gobart's* own Words) speak and tell the present State of the Air.

HAVING thus in Part given a rational and experimental Account to my Reader of the Instruments whereby the Principles of Hydrostaticks are more fully explain'd, especially in that of the Barometer, in which may be observ'd, one of the most wonderful Phænomena's in Nature; the Knowledge of which, as *Gobart* in his *Proæmium* or *Preface* to his *philosophical Tract*. of the *Barometer*, is more difficult than the Flux and Reflux of the Sea; the *Æstus* or Ebullition of the Sea (says he) owes its Motion to the Increase or Decrease of the Moon; but this may not improbably be attributed to a more potent Cause, and in this the Flux of the Barometer exceeds that of the Sea; because nothing precedes nor follows that, but from this follow various things, as Rain, Snow, Hail, Wind, Tempests. Nor is it easy to know the Cause of this Ascent or Descent, and what they portend, proves to be a laborious Enquiry. To follow our learned Author

THIS Instrument shews not only the present, but the future State of the Weather; by its Descent, is shewn Rain; and by its Ascent Serenity of Weather; sometimes it is serene after it

210 *An Introduction to a General System*

descends, and when it ascends it is rainy; by its Ascent is denoted Snow or Hail, by its Descent Winds and Tempests; *when the Mercury is elevated in a little Time, the following Serenity does not last long, and when it descends quickly, neither is the following Rain of any long Continuance; but when its Elevation is slowly, a more lasting Serenity; on the contrary, when it falls slowly, a constant Rain follows.* Oftentimes when it does not ascend much it is serene, and when it descends but little it nevertheless rains much, all which is owing to the different Gravity or Disposition of the Atmosphere, in the various Seasons and Turns of the Year.

THE slower Ascent of the Mercury, shews that a slow Condensation and Depuration of the Air is made from the aqueous Vapours, that are therein; and so a slow Condensation and Cleansing of the Air is necessarily join'd with a longer, as the slower Ascent of the Mercury shews a shorter Serenity following; for a slow Condensation is the Cause, that all the Particles of Air are more interwove amongst themselves, and on the contrary, that the aqueous Particles necessarily express themselves the clearer by the longer Relaxation and Expression of them; to be more plain, a notable Ascent, and which shews the Serenity of Weather; (but that which is not lasting) is that when it rises to a Finger's Breadth in a very little Time, to wit, in the Space of 12 or 15 Hours.

THIS Difference in the Rise of the Mercury (as has been often Times noted) is from the different Gravitation of Weight of the Atmosphere, for as *Gobart* Dub. 3. Pag. 161. *Mercurius multum ponderat, ergo debet dari magna mutatio in aere, ut ipsi æquiponderat*: And from this he says, that Mercury is to Air as fifty thousand to one, as he collects from *Kircher*. For sweet Water being to Air as 1000 is to 1; so Mercury is to Water as 15 is to 1, and consequently that Mercury is to Air, as one is to 50 Millions; if therefore Mercury be rais'd to 40 Digits, that is to two Foot and a half, a Column of Air will be elevated above 37000 Foot.

Now as to the Height of the Atmosphere I have to observe, that this Calculation of *Kircher's* is apparently different to what others of later Date have made. Sweet Water is (by Dr. *Desaguliers* and others) reckon'd as 800 to 1, and the Difference between Mercury and Water is as 14 to 1, both which Sums being multiplied together make but 41200 (instead of the 50000 before set down by *Gobart* from *Kircher*.) Besides, the different Degrees of the superincumbent Weight of the Atmosphere one

upon another, according to general Estimation is such, that 'tis hard to assign any precise Height thereto, but it may be 4, 5, or 6 Miles more or less.

BECAUSE, I remember somewhere in the History of *Hungary* to have read of a Mountain which was about 4 Miles high, to the Top of which some curious Observators ascended, which Mountain was so high, as that they thought themselves above the very Top of the whole Atmosphere, all that was under them being heavy and blue, and that the View of the Earth below them was thereby intercepted &c. but that the Air where they were, was very subtle and serene; all which is a Demonstration of the Uncertainty of this Height of the Atmosphere, which has been the great Enquiry of many Ages. But to proceed with *Gobart*, from hence (says he) it may be easily collected how much the superincumbent Air presses upon our Horizon, and how much that Mutation of Air (*quoad Pondus*) is, whilst the Mercury is only elevated or depress'd to the fourth Part of a Finger, the Quantity of the elevated Mercury will give the requir'd Weight; from thence it may be gather'd, that it is not the protuberant Weight of the Column of Mercury only, which causes the Change of all the superincumbent horizontal Air; and it ought to be wondred at, if that whole Mutation or Change of Air taken by Weight, (both fair Weather and Rain,) as well in Winter as in Summer may be describ'd in the Compass of three Fingers, containing as it does the Vicissitudes of tempestuous Air, Rains, variable and fair Weather, even as vast Regions may be describ'd (in geographical Tables) in some small Circle.

To proceed, the Ascent of Mercury from the Point of great Rains, to that of common or variable, is a Sign of serene or fair Weather, which is prov'd first from Experience, and secondly because thereby the Vapours shall be fully squeez'd or press'd thereout, and the Condensation be so sufficient, that the Mercury must be carried up thither; and if you enquire why it could not ascend higher, it is answer'd, that its Weight does not require it.

It may indeed be from thence inferr'd, that the collateral Notes of the Barometer are superfluous, because it may be fair Weather, and yet nevertheless the Mercury does or will stand still, as well within the Limits of Rain or variable, as it would within the Limits of fair Weather; but this Inference or Allegation is deny'd, because they who have chiefly observ'd the Ascent and Descent of Mercury, have more frequently observ'd it to have rain'd, than to have been fair; and to have been tempestuous

rather than variable,, when it has come to the Mark of serene or rainy Air. And what has happened commodiously enough to those who have made Observations concerning the Barometer, will not happen so well to those who are unwilling to know the Causes and Effects of that Ascent and Descent.

ANOTHER Objection brought against the Barometer is that the same Air according to all Circumstances cannot cause both fair Weather and Rain, to which it is answer'd, that it may ponderate in the same Manner, altho' it be join'd sometimes with Rain and sometimes with fair Weather; for Mercury might stand above fair Weather and yet be join'd with Rain, because Vapours which have been mix'd with Air already condens'd, can never lose its Elaterium, because of its Condensation; and therefore tho' the Mercury might stand the higher, it might nevertheless rain, and that for the following Reasons.

FIRST, for that Air is subject to various Alterations which take their Rise (as I think I have before hinted at) from the thick Vapours of the Water, from the Exhalations of the Earth, and from the Effluvia of terrestrial Bodies, whether animate or inanimate, from Heat or Cold, or from Rarefaction and Condensation.

Secondly, These Vapours and Effluvia's are sustain'd in the Air, as Particles of a lighter Kind are sustain'd, by those which are heavier in Water; the Reason of which is (as before) for that the Liquidity or Cohæion of the implex'd Particles of which they are compos'd, are like Nets whose exterior Parts they fasten to the Lattice of a Window, as they may do from the different Causes, from which that Mixture is made; not only in the Bottom, but also in the superior and middle Parts, as is plain in Water, on which salt Water is generally put.

Thirdly, It may come to pass that one Species of Particles may over-top at one Time, which Particles may be over-top'd by others at another; for the Air is sometimes so full of Vapours, that the whole may seem as if it was Water, which either insinuate themselves into Bodies which are very porous, or stick to the outer Parts of denser and more polish'd Bodies, even as Marbles which are sometimes seen to distil, as it were Drops of Water, and which nevertheless are as so many igneous or fiery Particles mix'd with Vapours, which in rainy Weather are warm, and which are nevertheless cold, when it is not so; or when they are overcome by nitrous Particles, or by others which serve for the Formation of Hail or Snow.

Fourthly, That the disperst Particles of Water, don't make that which is sensibly so, (unless they are gather'd together) is evident in a Looking-glass; for the Air which we breath has Particles of Water mix'd therewith, which however does not make sensible or real Water, unless the Glass, where they are gather'd together, be mov'd nearer to the Mouth; for which Reason it is necessary thus to express it when we speak of igneous Particles, which do not make a sensible or real Fire in the Air, unless when gather'd together in one Body, from whence they break out into Lightening, Thunder and the like.

Fifthly, Air may be sometimes full of Vapours, and sometimes destitute of them: The Air is fill'd by their Insinuation, and evacuated by their Agitation or Pression, even as a Net grows dry through Agitation, or a Sponge or wet Cloth by Pression; Air also may be fill'd or clear'd of Vapours, sometimes slowly and sometimes quickly; when the Air is clear'd of Vapours slowly, it recovers its Elaterium and Weight slowly again, but when it is clear'd quickly it soon recovers its lost Particles; from all which follows the slow or precipitate Rise of the Mercury, which comes to pass immediately after the Air has recover'd its Weight, but more slowly from its Condensation.

Sixthly, It must be observ'd, that when more igneous than aqueous Particles abound in the Air, the Effect of Fire follows, which overcomes the Activity of the other Agent of Water, from whence the Heat and Rarefaction of the Air follows also. And when the Particles of Water superabound, then cold and condens'd Air follows. And if Heat and Cold be equally join'd in one Foot of Air (as is I think elsewhere hinted at) it will so temper their Influxes, and in a stated certain Time will constitute such an Air, that from thence will follow a moderate Elevation of the Mercury, which will be chang'd again by the Occasion of other Particles, either of Water or Fire. And truly here is discover'd the various Combination of these Particles, as well to the Elevation as Depression of the Mercury; neither does any certain Tempest add any thing of itself to the *Elaterium* or Weight of the Air, but on the contrary clears it.

For first of all the Weight of the Air is equal both in Winter and Summer, because in the Winter, a condensing Cold prevails; and in the Summer, the Material of new Air, which is continually elevated by the Sun, (even as the Smoak which we see in a serene Sky, which we see drawn by the Heat of the Sun from dry Ground) is nothing else but that new Material for Air which I have been just now describing.

FROM

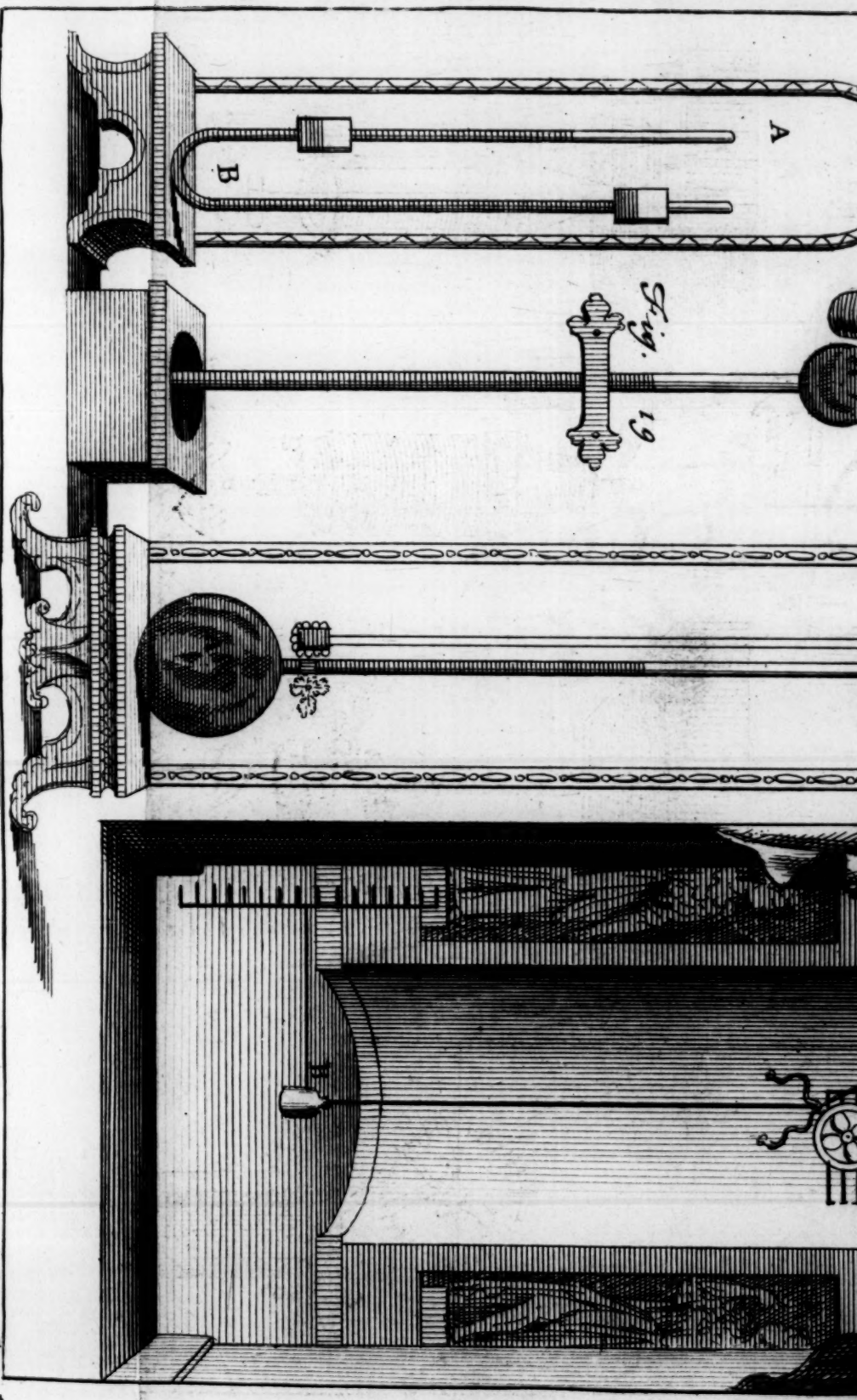
FROM whence it may be gather'd, that the Weight of Air may be equal, whether the Air be serene or rainy; if it rains, a condensing Cold may from some other Cause abound, if serene and fair a rarifying Heat; so also there may be a greater Weight of Air when there are Clouds, and lesser when there are none; if the Winds blow it will weigh less, if the Clouds are high and the Air is quiet, it will gravitate more, because (as has been before observ'd) when there is a greater Quantity of Air below than there is above, the superior Clouds do not exert their Elaterium or spring so much as when there is a lesser.

IN the second Place, Air may be condens'd in Summer as well as Winter, by reason of those cold Particles which are brought by the Force of North Winds into those Parts, and indeed in such a Plenty, that they may not only hinder the Rarefaction of the Air, but condense it in the same Manner as it us'd to be condens'd in the Winter; and this I have been told sometimes happens even in *Spain* and other warm Regions, where the Colds rush down from the Mountains with so great a Violence, (being there lodg'd by the northern Winds) that it strikes the Inhabitants as it were dead and benumb'd at once. In like Manner Air may be rarified by Heat as well in Winter as Summer, because such a Number of warm Spirits may be sent from the South, as may render the Air more warm, from which necessarily follows the Loss of Air's Equiponderacy, and consequently the Descent of the Mercury.

AND thus have I from *Gobart*, and other learned Authors, endeavour'd to state the Reasons, of the different Gravities of the Air; at different Seasons and Times, the greatest whereof is indeed from Air congregated and blown together by the blowing of Winds against Hills or Mountains, or by meeting and clashing with Air of the same or like Nature.

I shall but just answer one or two Objections more before I draw towards a Conclusion of this Chapter.

IT has been objected by the Enemies to the Barometer, that the slow Ascent of the Mercury, adds nothing to the future Serenity of the Weather; because by Observation it has appear'd to rise, and yet the third Day it rain'd; the Truth of which Fact is allow'd, for that two Days were not sufficient for the Purgation of the Air, more Time being required for the drying of Linnen much moistned with Water, than that which is tintur'd by a small sprinkling only. Air dry'd, and compress'd as it were of all its Parts, requires a moist Sky for many Days, (because



10ms. Sculp. 1

Fig. 22

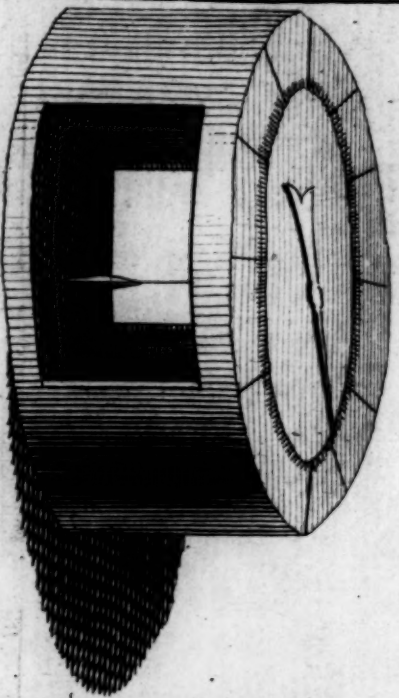


Fig. 12

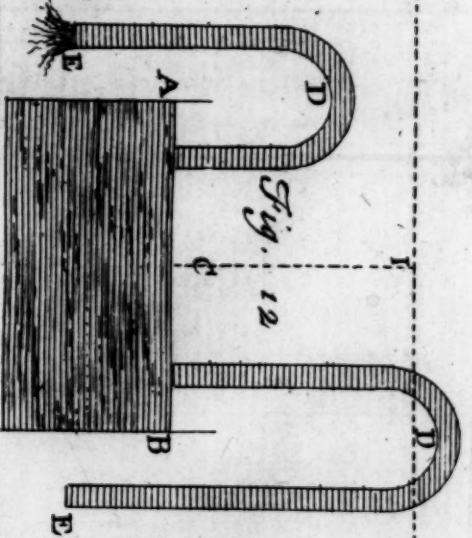


Fig. 13

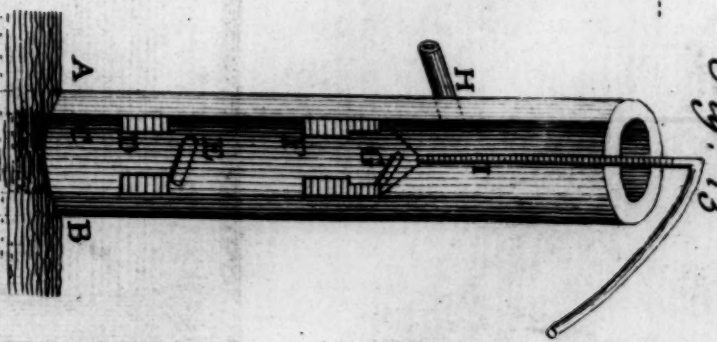


Fig. 14

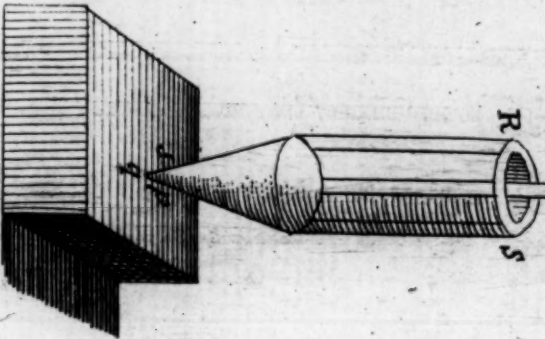


Fig. 15

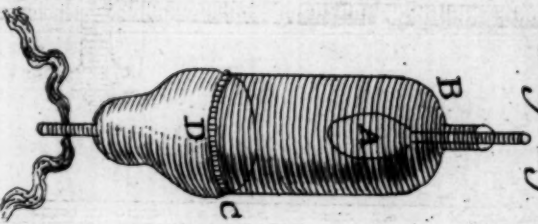


Fig. 16



Fig. 17

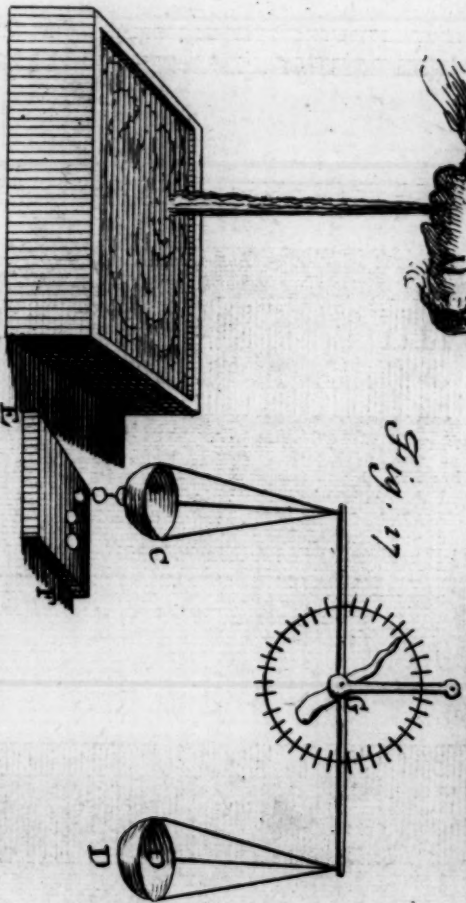
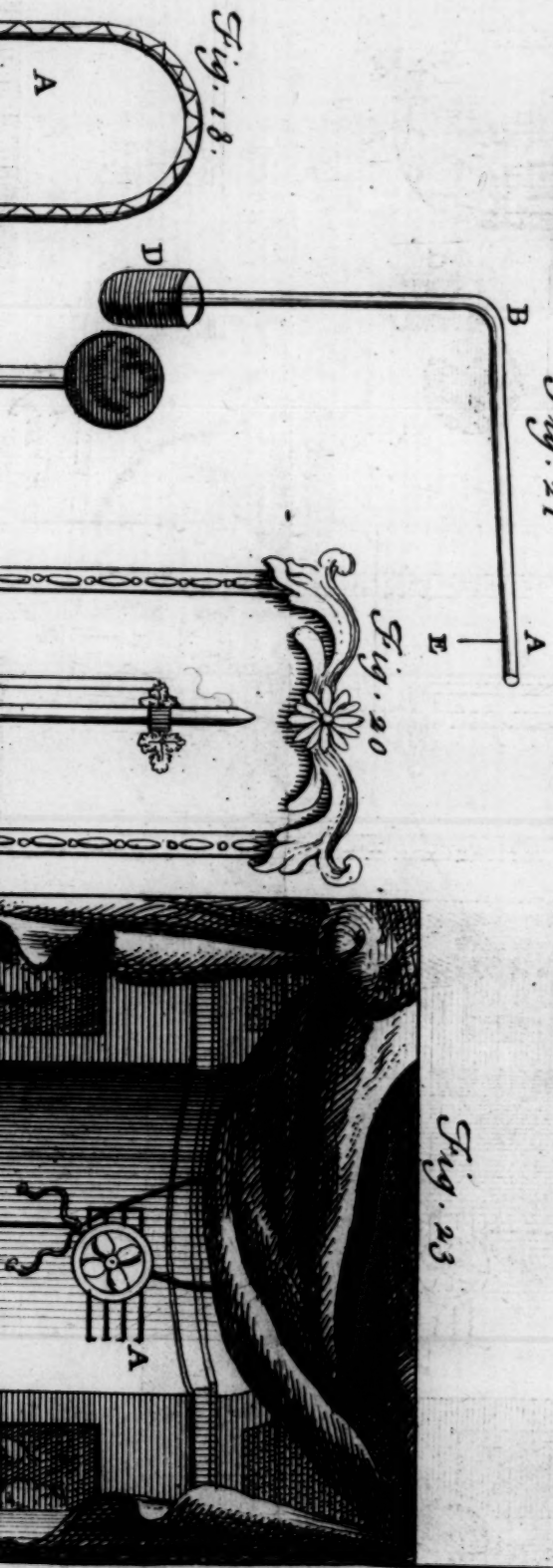


Fig. 21

Fig. 23



of Hydrostaticks and Hydraulicks. 215

(because it has need thereof) that it may sup up Vapours sufficient to fill the Clouds again.

FROM hence, and from some few other Observations of the like Nature, the Adversaries of the Barometer blame it; because say they, tho' it did ascend, yet nevertheless a future Serenity did not follow; for the Explanation of which it must be noted that Winds are only the Commotion, or in the Words of Dr. *Desaguliers* only a Stream of Air, which Air (as has been before observ'd) is in one Place more dense and ponderous, and in other Places less, even so that one Air which is more, may rush in upon another which is less dense by such its Commotion, from whence in like Manner it became a Wind; on the other Hand Air that remains at rest, in this or any other Horizon, after a slow Condensation, will undoubtedly give serene Weather; neither will Winds follow, unless it be observable in the Barometer, by the Descent of the Mercury; because according to our former Hypothesis, Air which is much agitated gravitates less, than that which is not agitated at all.

TO reduce what has been said in this Chapter to Practice, the Gravity of the Air being so very different, it ought to admonish the Engineer or Pump-maker not to fix his Sucket too high, for tho' Water may rise at one Time by the Weight of the Atmosphere to 32 or 33 Foot, yet at others it may not rise to above 25 or 26, and then in case the Water should sink in the Well which it often does, he may be frustrated in his Attempt, but of this more when we come to treat of Pumps. And from hence may Mortals know the different Effects that Air has on their Spirits, by the Density or Rarefaction of which they breath with more or less Pleasure; 'tis by the Condensity of this that the Pores of Bodies are so clos'd that they admit of no Cold, as it is by its Rarefaction, or I would rather express by its Humidity, that Catarrhs, Colds, and innumerable Distempers seize upon us.

I shall draw towards a Conclusion of what I have to say, concerning the Instruments whereby these Principles of Hydrostaticks are explain'd, with what the learned *Boyle* has observ'd concerning the Ascent and Descent of Mercury in an Air-pump *in Vacuo*, which I think undeniably proves, that it is Air and Air only that is the Cause of that Motion.

TAKE says he, *vid.* Vol. 2. Pag. 422. of his *physico-mechanical Experiments* "a slender and very exact Cylinder of Glass, "near three Feet in Length; and its Bore, being a quarter of an "Inch in Diameter; hermetically sealed, at one End, was, filled at "the other, with Quicksilver; Care being taken, that as few Bubbles,

216 *An Introduction to a General System*

bles, as possible, should be left in the Mercury. Then the Tube, being stop'd with the Finger, and inverted, was open'd into a long, slender, cylindrical Box, half fill'd with Quicksilver; when that in the Tube subsiding, and a Piece of Paper being pasted level to its upper Surface, the Box and Tube were, by Strings, carefully let down into the Receiver; and the Cover, by means of this Hole, slid along as much of the Tube, as reach'd above the Top of the Receiver: The Interval left betwixt the Sides of the Hole, and those of the Tube, being exquisitely fill'd up with melted Diachylon; and the round Chink, betwixt the Cover and the Receiver, were likewise, very carefully clos'd; upon which Closure, there appear'd no Change in the Height of the mercurial Cylinder; whence the Air seems to bear upon the Mercury, rather by Virtue of its Spring, than of its Weight; since its Weight could not be suppos'd to amount to above two or three Ounces; which is inconsiderable, in Comparison of such a Cylinder of Mercury as it would sustain. Now the Sucker was drawn down, and immediately, upon the Evacuation of a Cylinder of Air, out of the Receiver, the Quicksilver in the Tube subsided; and Notice being carefully taken of the Place where it stop'd, we work'd the Pump again, and mark'd how low the Quicksilver fell at the second Exsuction: But, continuing thus, we were soon hinder'd from accurately marking the Stages in its Descent, because it presently sunk below the Top of the Receiver: So that we could, from hence, only mark it by the Eye. And continuing pumping, for about a quarter of an Hour, we could not bring the Quicksilver, in the Tube, totally to subside. Then we let in some Air; upon which, the Mercury began to reascend in the Tube, and continued mounting, till having return'd the Key, it immediately rested at the Height it had then attain'd. And so, by turning, and returning the Key, we did, several Times, impel it upwards, and check its Ascent; till, at Length, admitting as much of the external Air, as would come in, the Quicksilver was impell'd up, almost, to its first Height; which it could not fully regain, because some little Particles of Air were lodg'd among those of the Quicksilver, and rose in Bubbles to the Top of the Tube.

"It is remarkable, that having, two or three Times, try'd this Experiment, in a small Vessel; upon the very first Cylinder of Air that was drawn out of the Receiver, the Mercury fell, in
"the

“ the Tube, 18 Inches and a half; and, at another Time, 19
“ Inches and a half.

“ W E, likewise, made the Experiment in a Tube less than two
“ Feet in Length; and, when there was so much Air drawn out
“ of the Receiver, that the remaining Part could not counter-
“ balance the mercurial Cylinder, it fell above a Span at the
“ first Stroke; and the external Air being let in, impell’d it up
“ again, almost to the Top of the Tube: So little matters it,
“ how heavy or light the Cylinder of Quicksilver be, provided its
“ Gravity overpower the Pressure of as much external Air, as
“ bears upon the Surface of that Mercury into which it is to
“ fall.

“ LASTLY, we observ’d, that if more Air were impell’d up,
“ by the Pump, into the Receiver, after the Quicksilver had re-
“ gain’d its usual Standard in the Tube, it would ascend still
“ higher; and immediately, upon letting out that Air, fall again
“ to the Height it rested at before.

“ BUT, in order to fill the *Torricellian* Tube with Exactness,
“ the Edges of the open End should be made even, and turned
“ inwards, that so the Orifice, not much exceeding a quarter of
“ an Inch in Diameter, may be the more easily, and exactly stop’d
“ by the Finger; between which, and the Quicksilver, that there
“ may be no Air intercepted, it is requisite that the Tube be
“ perfectly full, that the Finger, pressing upon the protuberant
“ Mercury, may rather throw some out, than not find enough to
“ keep out the Air exactly. It is, also, an useful Way, not quite
“ to fill the Tube, but to leave, near the Top, about a quar-
“ ter of an Inch empty: For, if you then stop the open End,
“ and invert the Tube, that quarter of an Inch of Air, will
“ ascend in a great Bubble to the Top; and, in its Passage, lick
“ up all the little Bubbles, and unite them with itself, into one
“ great one. So that, if by re-inverting the Tube, you let that
“ Bubble return to the open End of it, you will have a much
“ closer mercurial Cylinder than before, and need add but a very
“ little Quicksilver more, to fill up the Tube exactly. And,
“ lastly, as for such little and invisible Parcels of Air, which can-
“ not be thus gather’d up, you may endeavour, before you in-
“ vert the Tube, to free the Quicksilver from them, by shaking
“ the Glass, and gently knocking on the Outside of it, after every
“ little Parcel of Quicksilver is pour’d in; and afterwards, forcing
“ the Bubbles to disclose themselves, and break, by applying a
“ hot Iron near the Top of the Glass; which will raise the Bub-

218 *An Introduction to a General System*

bles so powerfully, as to make the Mercury appear to boil. I remember, that by carefully filling a short Tube, tho' not quite free from Air, we have made the mercurial Cylinder reach to thirty Inches, and above an Eighth; which is mention'd, because we have found, by Experience, that in short Tubes, a little Air is more prejudicial to the Experiment, than in long ones.

WE fill'd a glass Tube, about three Feet long, with Mercury; and having inverted it into a Vessel of other Quicksilver, that in the Tube fell down to its usual Height; leaving some little Particles of Air in the Space it had deserted: For, by the Application of hot Bodies, to the upper Part of the Tube, the Quicksilver would be a little depress'd. Lastly, having put both the Tube, and the Vessel whereon it rested, into a convenient wooden Frame, we placed them together in a Window of my Chamber.

AND during several Weeks, that the Tube continu'd there, I observ'd, that the Quicksilver did sometimes faintly imitate the Liquor of a Thermometer; subsiding a little in warm, and rising a little in cold Weather; which we ascrib'd to the greater, or lesser Pressure of that little Air, which remain'd at the Top of the Tube, expanded, or condens'd by the Heat, or Cold of the ambient Air. But, the Quicksilver often rose, and fell in the Tube very considerably, after a Manner, quite contrary to that of Weather-glasses, where Air is at the Top; for sometimes, I observ'd it, in very cold Weather, to sink much lower, than at other Times, when the Air was comparatively warmer. And sometimes, the Quicksilver would, for several Days together, rest almost at the same Height; and at others, it would in the Compass of the same Day considerably vary its Altitude, tho' there appear'd no Change, either in the Air abroad, or in the Temper of that within my Room, nor in any thing else, to which such a Change could reasonably be imputed; especially considering, that the Space wherein the Mercury continued unsettled for five Weeks, amounted to full two Inches; descending in that Time about $\frac{2}{18}$ of an Inch from the Place where it first settled, and ascending the other Inch, and $\frac{7}{18}$; and when we took the Tube out of the Frame, after it had staid there part of *November*, and *December*, a large Fire being then in the Room, we found the mercurial Cylinder to be above the upper Surface of the stagnant Mercury $29\frac{3}{4}$ Inches.

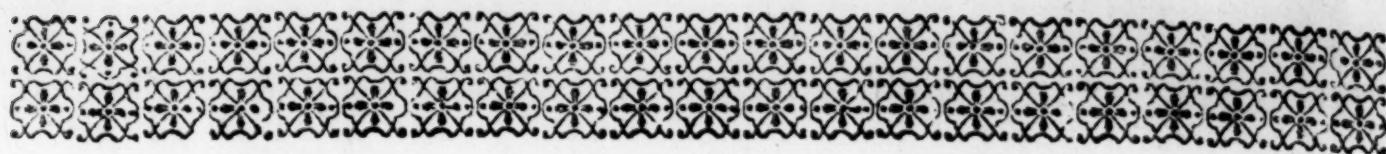
“ SUCH an Inequality in the Rise, and Fall of the Mercury
 “ will, I fear, render it difficult to determine by the Barometer,
 “ whether the Moon be the Cause of the Tides, especially, till
 “ the Reason of this odd Phænomenon be certainly known; which
 “ seems principally to depend upon considerable Alterations in the
 “ Air, in Point of Rarity and Density,

“ 19. WE took a Tube of Glass, about four Feet in Length,
 “ hermetically seal’d at one End, fill’d it with common Water,
 “ and inverted the open End, beneath the Surface of a Vessel of
 “ Water. Then this Vessel, with the Tube in it, being let down
 “ into the Receiver, the Pump was set on work; when, till the
 “ Receiver was moderately exhausted, the Tube continu’d quite
 “ full of Water; it being requisite, that a great Part of the Air
 “ contain’d in the Receiver should be drawn out, to bring the
 “ remaining to an Equilibrium, with so short a Cylinder of Wa-
 “ ter. But, when once the Water began to fall in the Tube,
 “ each Exsuction of Air made it descend a little lower; tho’ no-
 “ thing near so much, nor so unequally, as the Quicksilver did.
 “ The lowest, we were able to draw down the Water, was, to
 “ about a Foot above the Surface of that in the Vessel. And,
 “ when the Water was drawn down thus low, we found, that
 “ by letting in the outward Air, it might be immediately im-
 “ pell’d up again, to the higher Parts of the Tube.

“ Upon making this Experiment in a small Receiver, we ob-
 “ serv’d, that at the first Exsuction of the Air, the Water usually
 “ subsided several Inches; and at the second, sometimes near two
 “ Feet; whereupon letting in the external Air, the Water was
 “ impell’d up, with a very great Velocity.”

THE same learned Author Pag. 453. of his Pneumatics, that
 from the Computation of the Weight of Air to Water, it might
 be expected should be decided the great Controversy about the
 Height of the Atmosphere &c.”

To conclude this Chapter with the learned Dr. Clarke in his
 Notes on *Robault* and in *Philosoph. Transac.* No. 181. 292. this
 Difference which is observ’d in the Gravity of the Atmosphere
 (let its Height be what it will) the Reason (says he) why the
 Quicksilver in the Barometer should stand lower, when the Air
 is thick, dry and clear; and lastly the Barometer varies least be-
 tween the Tropics, because the Wind is there almost always
 gentle, and blows the same Way. And thus much of the Know-
 ledge of Hydrostaticks from the Barometer and other Instruments.



B O O K. II.

C H A P. XVI.

*Of Air and its Effects in Hydrostaticks, by its Elasticity:
As also of its Dilatation and Compression.*



ELASTICITY, as defin'd by *Wallis* (*Cap. 13. Def. 1.* of his *Mechanicks*) is that Body, which, being thrust by Force out of its own proper Place, endeavours to restore it self again to its primitive Form and Figure, and that *vis elastica* has its Derivation *ab ἐλαύνω, agito, abigo, excutio, expello*; and that *ἐλατήρ* is of the same Original; which *elater* signifies in our Language a *Spring*, from the same Root that *Salire* or *Exsilire* signifies in the *German* and *Danish* Languages, *Springen* or *Springhen*; and from thence a springy Body is call'd *Corpus Elasticum*, an elastick Body; and a Body thus elated is said to be endued (*vi elastica*) with an Elasticity or Springiness.

It signifies also, and perhaps more frequently in a metaphorical Sense, *germinare*, even as Buds (*exsiliant*) that is, bud or spring out of a Tree; and from thence *vernum* is called Spring, because 'tis chiefly then that all things put forth: For this Reason also a Fountain or small Rivulet is call'd *aqua saliens*, a *Spring*, *ob salientem aquam*, as *Wallis* defines it; it is called *exsilire* also from the Springing of a Mine, as that learned Author will have it.

BUT to proceed, As a soft Body is that which when press'd yields to the Stroke, and loses its former Figure, and cannot recover itself; so an elastick Body is that which tho' it yields for a while to the Stroke, yet can afterwards recover its former Figure, by its own natural Power; and if it can do this with the same Force, as that which press'd upon it, we say it is perfectly elastical.

of Hydrostaticks and Hydraulicks. 221

SOME of Note there are, which allow little or no Elasticity to any thing, but Air, and *Marriotte* himself, Pag. 68, of his *Hydrostaticks*, as translated by Dr. *Desaguiliers*, says that Water has no sensible Elasticity, and makes (as is elsewhere observed) an *equilibrium* with other Bodies only, by its own Weight or Impulse: But the laborious *Harris* (in his *Lexicon Technicum, sub titulo E.*) says, If there were no such thing, or if in other Words this Elasticity was not almost general, the Laws of Motion found out by Mathematicians (who, heretofore I add, knew little of Hydrostaticks) about the Percussion of Bodies, would hold universally, and be without Exception true, and the Body (as Mr. *Keil* in his Introduction *ad veram Physicam*, Pag. 151) would move jointly that Way towards which the stronger Body tended before the Shock or Percussion, and with a Celerity easily determinable by the Laws of Motion.

BUT because there are few Bodies (many of which are condens'd and hardish) without some Degrees of Elasticity, even soft Clay, Wax, cast Lead, &c. according to *Wallis*, containing in them some Particles of elastick Matter: From hence it is (I say) that Bodies which strike or move against one another, do spring, recede, or leap back, and move with different Degrees of Velocity, sometimes one Way, or sometimes according to the Direction of the Line, or the different Degrees of Velocity or Strength in the Percutient or Weight of the Body percuss'd or struck against.

IF you imagine (says a curious Author on this Subject) a String or Wire to be strain'd or fastned firm at each End; then 'tis plain, that if the middle Part of the String, or any other, be drawn by the Hand, or press'd by a Weight out of that right Position in which it was at first, that if the Force which moved it, be not greater than the elastick Force of the String, the String will fly back again; and if the Weight or Body be not removed, it will drive it before it, as the String of a Cross-bow doth an Arrow or a Bullet, and the acquired Velocity of the String will carry it beyond its first right Position towards the opposite Parts, and that so far as till the Motion that Way be equal to the Elasticity of the String; and then being quite destroy'd, the String will return again as before: And thus springing forwards and backwards, would (abstracted from the Resistance of the *Medium*) like a double Pendulum, make continual Vibrations.

THUS also, if you suppose any Weight to fall on an immovable, fix'd, and perfectly elastick Body; on the Contact of each with the other, the Parts of the elastick Body will spring back, or recede inwards, till the elastick Force be rais'd up equal to the Momentum
of

of the falling Body, and then this latter, ceasing its elastick Force, will cast the Body upwards, or from it, as was impell'd against it, recovering its former Figure again; but if both the Bodies being elastick, neither of them being fix'd or movable, then the elastick Force will act equally in each Body, and produce equal Mutations of Motion.

THE usual Methods of judging whether Bodies are endued with this elastick Quality or not, is to enquire, whether, on being struck, they give any *Tinnitus* or ringing Sound, or indeed any sensible Noise; for if they do, you may in some measure conclude them to be elastical, and that they are so in Proportion to the Strength and Acuteness of the Sound they emit: And *Wallis*, *Cap. 13. Prop. 1. Pag. 692.* of his *Mechanicks* aforesaid, doubts not but there is an elastick Quality even in Marble, Wood, Earthen Ware, hard Metals, and in innumerable other things, which is discoverable not only by the Sound, but is easily observ'd both by Inspection and Touch, from that Shaking and Trembling it is so notably endued withal.

THE curious and inquisitive Mechanick and Philosopher *Gobart* says, (a) That Elasticity is caus'd from the innate Inclination of its Parts, endeavouring to obtain a larger Space for themselves. But to draw towards an End, and to conclude this preliminary Discourse of Elasticity, let us sum it up with the well knowing *Wallis*, who, in his *Definitions*, *Cap. 13.* says, That from whence, or however situated this Elasticity in Bodies is, he does not pretend to enquire, nor could the Nature of it be explain'd so well as to satisfy either the Reader or himself in it. It is sufficient, that there is such a thing in Nature, that when it is press'd, it will return and rise again; but how this Body is restor'd (especially in Air) to its former Position, no body can perfectly discover: But to make the strictest Enquiry we can of this Force, intersper'd as it is thro' the whole Compass of Nature, let us in the next place take a View, contain'd as it is, under the general Denominations of Elation, or springing forwards, and of Resilition or Reflection, the reflecting or leaping back of Bodies one from another; to which may be preliminarily set down what relates to the Explanation of Rarefaction, Dilatation, Extension, or the Condensation or Expansion of Air.

Gobart tells us (*Par. 1. Pag. 102. Prædict.*) That Rarefaction is not to be confounded with Dilatation, nor Dilatation with Elasti-

(a) Elasticitas fit ab innatâ inclinatione partium conantium ex se majorem locum obtinere (vid. *Par. 1. Pag. 102. of his Tractat. Philosoph de Barometro.*)

city; the last Word is already enlarged upon, as endeavouring to obtain larger Room for the Motion of its Parts, Dilatation extrinſick, ſo as that the Order of its Parts cannot be ſeparated, but Rarefaction is compos'd in this, that thereby the Order of its Parts may be chang'd, and that the Parts of which it is compos'd; may be ſeparated one from another: On this Account it is, that Rarefaction is made by the Means of intromitted Heat; but Dilatation by the Means of extrinſick Traction, or the Intromiſſion of another Body; but Elaſticity by ſome intrinſick Means, whereby one Particle of Matter acts againſt another of its own Accord; but Extension, in the Order of which it is ſaid that a Body is rarified, is that which belongs to that Body the Moment of its Production.

NOR are theſe Definitions (eſpecially of Air) idle Speculations only, but real and effective Truths, and ſuch, by which ſome of the greateſt Phænomenas in Nature are demonſtrated and explain'd, and which is eſpecially of the greateſt Uſe in Hydroſtaticks.

TO proceed to Fact; Air (as our ingenuous Author has it) has a Property greater than other Liquids; that is, that it can take up a greater or a leſſer Space, according as it is compress'd with a different Force; and as ſoon as that Force is diminish'd, it expands it ſelf again, and by Reason of this Analogy of the Effects of Air with other Bodies it is call'd elaſtick.

THAT Air may be compress'd, appears from what the oft-quoted *Boyle*, *Wallis*, and other Authors have ſaid of extenſive Solidity, Vacuity, &c. particularly in the Experiment of a Syringe, ſo cloſe ſhut up at the End of it, that it will reſiſt the Piſton ſo, as that you can't thruſt it to the Bottom with all the Force you have, unleſs you break your Machine. That Air may be dilated, will appear from the following Experiment made uſe of by *Graveſande* and others, (*Fig. 5. Tab. Seq. Exper. 1.*) Take the Tube A B cloſe at the End A, and pour Mercury into it, ſo that there may be ſome Air left in the Tube, which when in the State of the external Air, will take up the Space A C, if the End B of the Tube be immers'd into Mercury in a Veſſel, the Mercury in the Tube will deſcend to g, and there remain. The Height *ig* differs very much from the Height of the Mercury in the firſt Experiment of the aforegoing Chapter (concerning the Gravity of Air) which does not ariſe from the Gravity of the Air in the Tube; for its Weight is too little to produce any ſenſible Difference in the Height of the Mercury: The Expansion of the Air cauſes this Effect; and from this Experiment may be deduc'd this Rule, that the Air dilates it ſelf

self in such a Manner, that the Space taken up by it is always inversely, as the Force by which it is compress'd.

(To proceed) the Compression by which the common or external Air is compress'd, is the Weight of the whole Atmosphere, which is equal to a Pillar of Mercury, of the Height, bf , *Fig. 1.* Therefore the Compressive Force may be express'd by that Height; the Space taken up by the Air in the Tube where it is compress'd by such a Force is AC .

BUT in the last Experiment the Pressure of the Atmosphere exerts two Effects; it sustains the Pillar of Mercury ig , and it reduces the Air in the Tube to the Space gA ; if the Force gi be subtracted from the Pressure of the whole Atmosphere; that is, if the Height gi be taken from the Height bf (*Fig. 1.*) there remains the Force by which the Air is compress'd in the upper Part of the Tube; but this Difference of the Heights of the Mercury bf and gi is always to bf as AC to Ag ; that is, their Forces are inversely as the Spaces; and this Rule holds good also in compress'd Air.

EXPERIMENT 2. (*Fig. 6. Tab. Seq.*) Take a Curve Tube $ABCD$ open at A , and shut at D ; let the Part BC be filled with Mercury, so that the Part CD may contain Air of the same State or Tenour as the external Air; therefore the compressing Force is the Column of Mercury, whose Height is bf , *Fig. 1.* and by this Height must this Force be express'd, as in the foregoing Experiment; let the Space taken up by the Air be CD ; pour Mercury into the Tube $A.B.$ that it may rise up to g ; the Air will be reduc'd to the Space eD : Now the compressing Force acts as strongly as a Column of Mercury of the Height fg , and also the Pressure of the external Air upon the Surface g of the Mercury; this Force is express'd by the Heights fg in this Figure, and bf in *Fig. 1.* and this Sum is always to bf (*Fig. 5.*) as CD to eD ; and again the Forces are inversely as the Spaces.

THE Elasticity of Air is also as its Density; for the last is inversely as the Space taken up by the Air; therefore the Force compressing the Air, is equal to that by which the Air endeavours to expand it self; and this Force is its Elasticity: And hence it follows, that the Air in which we live is reduc'd to the Density which it has near the Earth, by the Pressure of the superincumbent Air, and that it is more or less compress'd, according to the greater or lesser Weight of the Atmosphere; for which Reason also the Air is less dense at the Top of a Mountain, than at the Foot of it, as being compress'd by a less Weight; that is, in what

when you are at the Top of the Mountain ; for as you are nearer the Top of the Mountain, you consequently have less Weight lying upon you, a Column of Mercury, (as has been before observ'd) of 29 Inches high below a Hill, being of equal Weight with the Pressure of the Atmosphere, and a Pillar of Water of thirty two Foot equal thereto ; but if you carry a Tube of Mercury to the Top of a Hill 100 Foot high, the Mercury will descend a Quarter of an Inch.— Which proves that the lower Air is elastick, or expands it self according to its Density.

How far this Property of expanding it self is or may be extended, is not certainly known, notwithstanding the curious Experiments that have been made to find it out ; and it is very probable that it cannot be determin'd by any Experiments: Nevertheless, (as a learned Author has it) if you compare the following Experiment with the Experiment of the Air compress'd in a Pump, it will appear that the Air may take up 20000 Times more Space in one Case than in the other.

(EXPERIMENT 3. *Fig. 7. and Tab. Seq.*) Let the Glass A B about fourteen Inches high be exactly fill'd with Water, having a Brass Cap fix'd to the End of it at B, by which it is to be screwed to the Pump, that is before mention'd, (*vid. Fig. 6.*) by drawing out the Piston of the Pump, the Water descends into it by its Gravity ; and the Place in the upper Part of the Vessel is void both of Air and Water ; the Air Bubbles in the Water which are now compress'd, because the Air does not act upon the Surface of the Water, expand themselves, and rise up to the Surface of the Water ; in that Motion the Bubbles are accelerated, so as not to be seen distinctly near the Surface ; upon Account of their very swift Motion, they also grow bigger, as they ascend ; and if you compare the Diameter of a Bubble at B with its Diameter, when it is come almost up to the Surface of the Water, or so far as it may be seen distinctly, its Diameter is at least four Times as great as before.

THE upper Part of the Glass, as was said before, is intirely void of Air, for the small Quantity of Air, which is continually going out of the Water is not to be taken Notice of here ; therefore the Air Bubbles near B, which are a Foot below the Surface of the Water, are compress'd only by the superincumbent Water ; which Pressure is to the Pressure of the Atmosphere nearly, as one to thirty two, in which Ratio also is the Space taken up by the Air, when 'tis compress'd by the whole Atmosphere, to the Space taken up in the Bubbles before mention'd ; their Diameter, as has been

G g

before

before said, becoming equal: That is, the Bubble becoming sixty four Times greater than at first it was, and so the Space taken up by the Air in this last Case, is to the Space (as the learned *Gravesande* has it) taken up by the Air when compress'd by the Atmosphere, as 64 Times 32 (which is as 2048) to 1; and the Air compress'd by the Atmosphere is reduct (according to that learned Author) to a Space ten Times less in a forcing Pump; and so the Density of this Air is as 20480 to 1. and extracting the Cube Roots of these Numbers, we shall find, that the Distances between the Center of Particles in these two Cases are according to that elaborate Author, as 27 to 1.

BUT *Wallis*, in *Cap. 14. Prop. 13.* of his *Mechanicks*, allows a great deal more for the different Degrees of Dilatation and Compression, than *Gravesande* does, and makes the Difference between Air compress'd into its narrowest Compass, and Air dilated to its greatest, to be as 550000 to 1. concerning which, I shall, in the Course of this Chapter, treat more at large; and to proceed with the learned *Gravesande*, shall conclude, that the Particles of Air are not of the same Nature with other elastick Bodies, for that the single Particles cannot expand themselves every Way into 27 Times the Space, and so be encreas'd 2000 Times, preserving their Surfaces free from every Inequality or Angle, because in every Expansion or Compression, the Parts are easily mov'd one against another; but as Air (which seems to agree with what *Wallis* has advanc'd on this Head) may be dilated much more than in this Experiment, it follows, that the Air consists of Particles, which do not adhere or touch, but repel each other. To conclude what may be said as to the Elasticity of Air; *the Effects of it are the same as its Gravity*, and included Air acts by its Elasticity, just as Air not included does by its Weight.

THE Air which is loaded by the Weight of the whole Atmosphere, pressing every Way from the very Nature of Liquids; and the Force which it exerts does no Way depend upon that Elasticity; because whether you suppose Elasticity or not, that Force which arises from the Weight of the Atmosphere, and is equal to it, can no Way be chang'd, but as the Air is elastick, it is reduc'd to such a Space by the Weight of the Atmosphere, that the Elasticity which reacts against the compressing Weight is equal to that Weight. But the Elasticity encreases, and diminishes as the Distance of the Particles diminishes or encreases; and it is no Matter whether the Air be retain'd in a certain Space by the Weight of the Atmosphere, or any other Way; for in either Case it will

expand it self with the same Force, and press every Way; therefore if the Air near the Earth be included in any Vessel, without altering its Density, the Pressure of the included Air will be equal to the whole Weight of the Atmosphere.

EXPERIMENT 4th, Fig. 8th. Tab. Seq. Take the Tube before mention'd, and immerge it in Mercury included in the Glass D C, so that the Air pressing upon the Surface of the Mercury contain'd in the Vessel, may have no Communication with the external Air; the Mercury in the Tube is sustain'd at the same Height by the Elasticity of the Air, as it was sustain'd in the open Air.

AND this lets us in to the clear Understanding of a Doubt that I have my self (as well as others) often had, how it comes to pass, that the Water is rais'd in Pumps to the same Height in an enclos'd Well, as it does in the open Air in a Pond, or the like, when there is a Kerb, and other pitching and paving that shuts it up so, as that not only the Weight of the Atmosphere, (but even the ambient Air it self) seems to be in a great Measure excluded. And of this the learned *Desaguiliers* in his experimental Philosophy has given us some notable Experiments.

WHICH as well as other Experiments, which have been exhibited by Dr. *Desaguiliers*, *Messieurs Watts*, *Hauksbee*, and others, are sufficient Demonstrations of the Elasticity of Air. But to be a little more particular, or in other Words explain and give an Account of the Extent of this Elasticity, which is discover'd by the pneumattick and other Engines,

Varenius Prop. 10. Par. 329. of his *Geogr. &c.* relates, That the most serene Air (as he there calls it) may be so rarified by Fire, that it will take up a seventy times larger Space than before; and that it may be so condens'd by a Pneumattick Wind Gun, that it will take up only a 60th Part of the former Space: But *Wallis Cap. 14. Prop. xiii.* gives a more perfect History of the Compression or Dilatation of which Air is capable, than any other Author yet extant.

Mersennus (he tells us) long ago, by the Help of an *Æliople*, dilated the Air so, that it took up a Space 70 times as big as it was at first. And Mr. *Boyle*, without the Help of Heat, by elastick Force only, with which Air was indued, found it to dilate it self first to 9, then to 31, then to 60, and then to more than 152, which is above double to what *Mersennus* could by the Help of Heat arrive to, as may be seen *inter experimenta sua Physico-mechanica de aeris elatere, &c. Experim. 6.* but after that, in his Experiments *de admiranda aeris rarefactione*, he relates that in eight or nine Years time, he found that Expansion to be much lar-

ger, even to 8000 (by its elastick Force only, without the Help of Heat) and having repeated the Experiment, at which our Author was also present, he found them to be larger still; and therefore having appointed another Experiment, he found it come to 10000 and above (to use his own Words, *Pa.* 737.) *Seu plusquam decies Mil-
lecuplum loci quam prius occupaverat idem aer, imo ad locum occu-
pandum vicibus, 137 69.* And amongst other very ingenious and subtle Experiments of the *Florentine* (*Torricelli*'tis suppos'd he means) publish'd a few Years since, it is found, that Air, not only without the Help of Heat, but also without the Help of the Air Pump which Mr. *Boyle* used, might expand it self into a Space 173 times larger than at first it was.

IN like Manner, as to its Compression from the Experiments of *Mersennus* just mention'd in a Scloppetum or Wind Gun, where, endeavouring to compress it, a Globule of Air, like a Flame of Fire, it burst out with great Force, and, notwithstanding all the Industry they could possibly use, they could not contract it into above a fifteenth (tho' *Varenius* before recited says a 60th) Part of the Room it before took up; and in the compressive Engine which was made for the Use of the Royal Society of *London*, Experiments were made, by which it was found, that Air could not be compell'd into a Space above $\frac{1}{15}$ or $\frac{1}{12}$ of its wonted Space; and Mr. *Boyle* has the same in his Experiments concerning the *Condensation of Air by Cold*, in which he found, that by the help of Ice mix'd with, or made by Salt, and put into a glass Vessel in which Air was included, that it could be contracted only as 147 to 158, or thereabouts, which is a great deal less than was generally obtain'd by Mechanick Force; for in that it lost little less of its first Space than $\frac{1}{158}$, which is almost as $\frac{1}{147}$; and tho this was look'd upon to be a great Compression, yet he tells us, that whilst that Cold was so us'd, that it abundantly suffic'd to the Congelation of Water, and was much greater than the severest Winter Weather we have, being in like manner mix'd in a Vessel (wherein was Ice or Snow mix'd with Salt) wherein also there was a little Air and much Water included, the Water being expanded by the Force of the Cold, so as to be nearly congeal'd, compress'd the Air in such a Manner, that it was included in $\frac{1}{158}$ Part of its first Space; but if they had endeavour'd to contract it more, the Vessel it self must have been broke, which Contraction or Condensation (says *Wallis* p. 738) tho it be much less than the Expansion or Rarefaction just mention'd, yet it is a great deal more than the Cold of any great Winter, or any Mechanick Force yet produe'd could effect.

Fig: 1

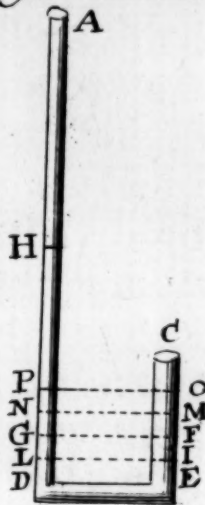


Fig: 2

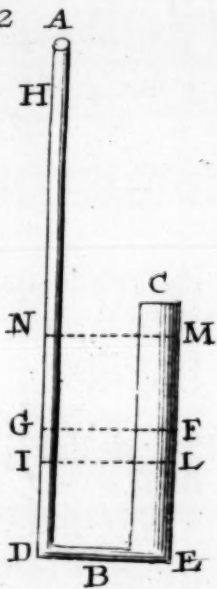


Fig: 3



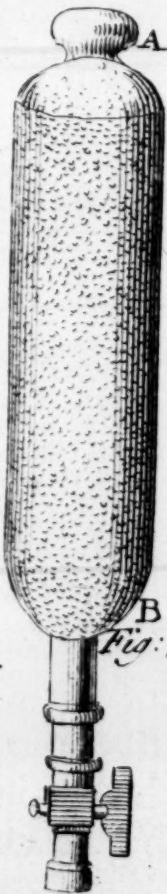
Fig: 5



Fig: 6

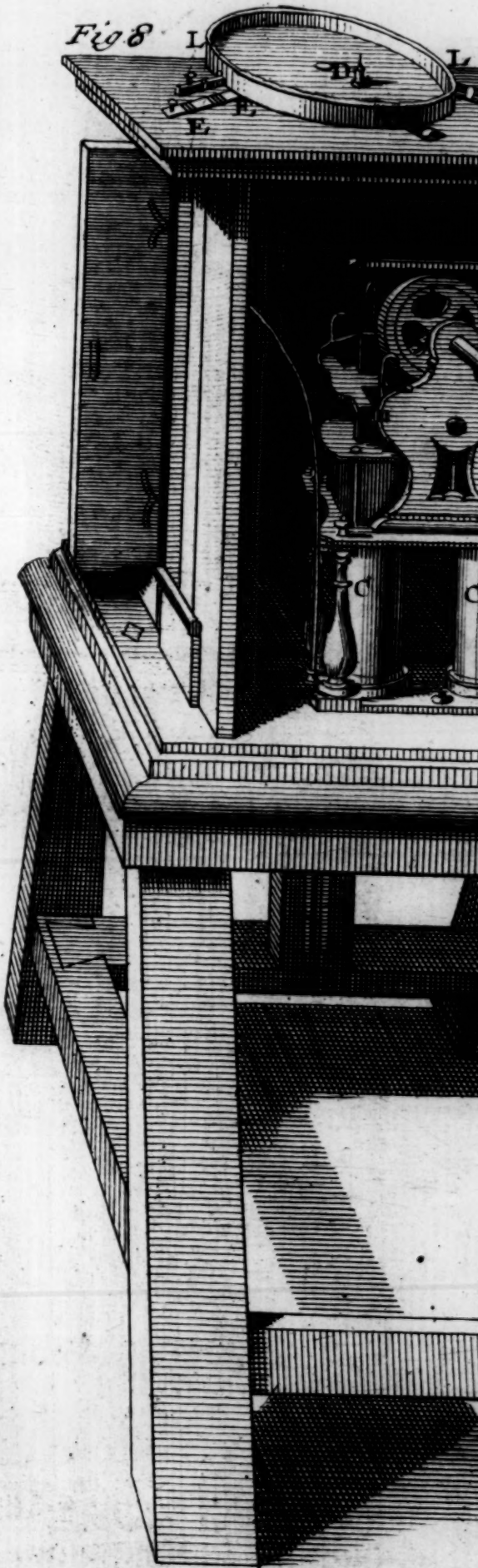


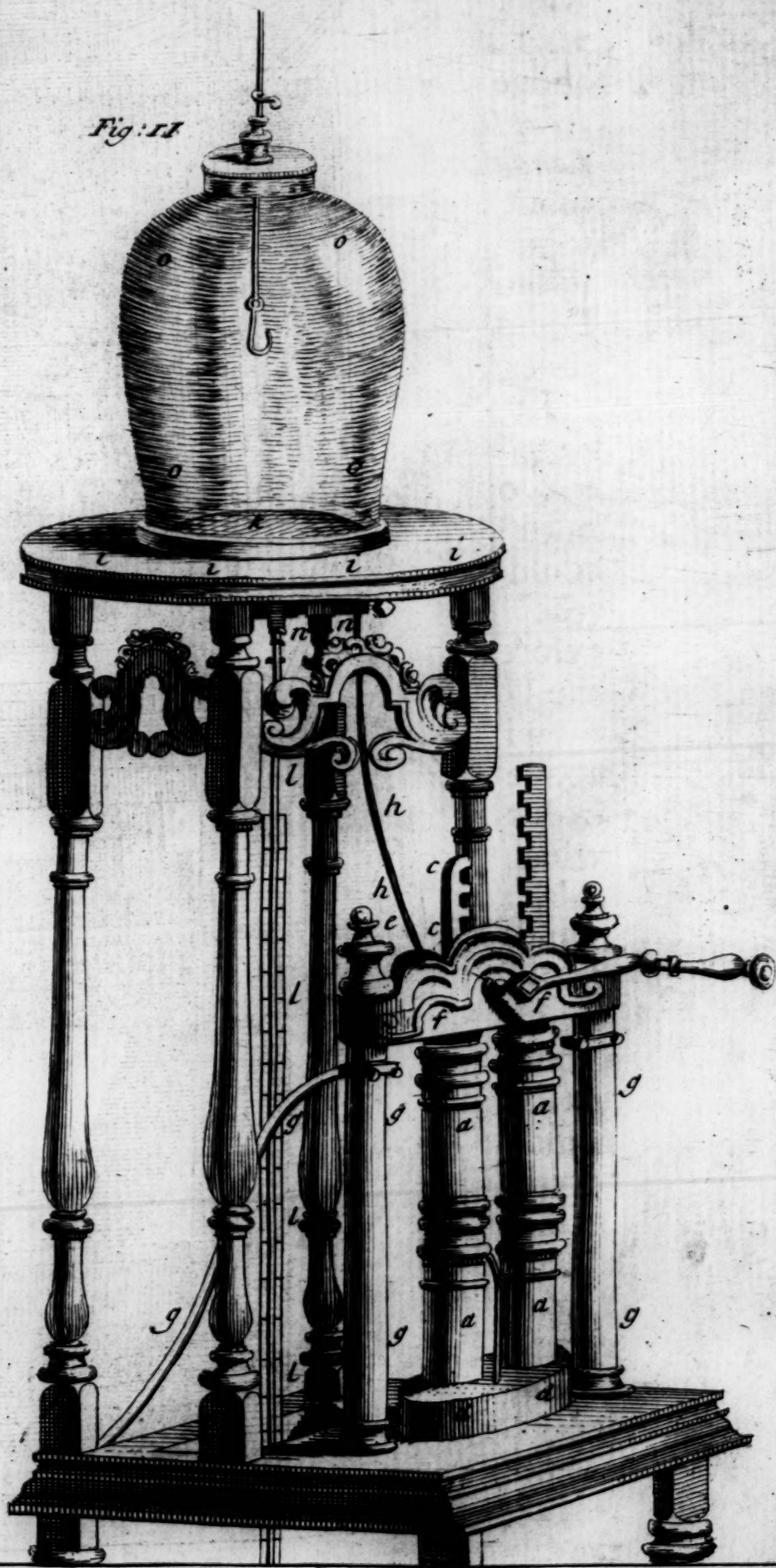
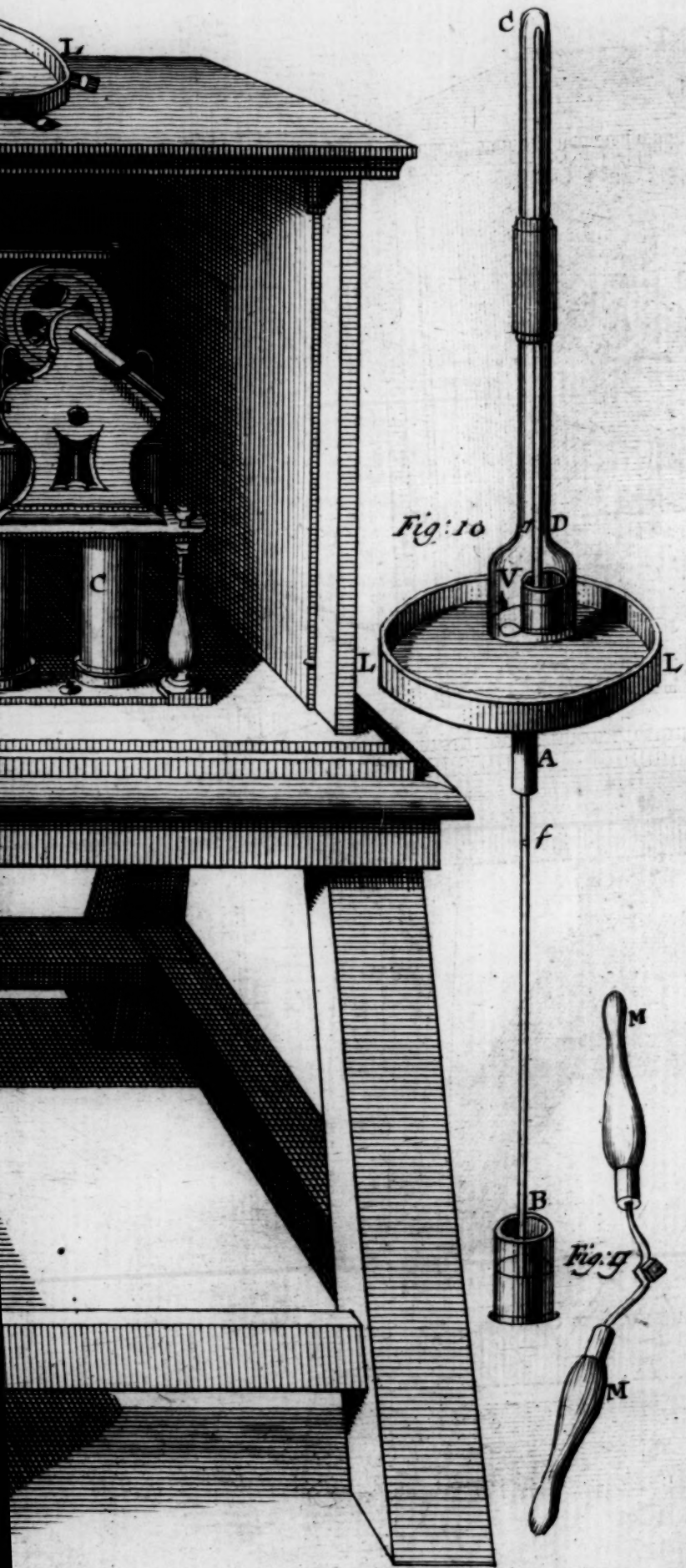
Fig: 7



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Fig: 8





of Hydrostaticks and Hydraulicks. 229

So that if we put the two great Articles of Rarefaction and Condensation together, that is, that Air dilated is as 13679 to 1, and compress'd Air as 40 to 1, and multiply the one by the other, the Product will be 550760 to 1, as has been before set down in the Preface.

AND so much of the Condensation and Rarefaction; or, in other Words, of the Compression or Dilatation of Air: And in Confirmation of that Elasticity and Springiness, which it receives from one of the great Laws of Nature, I mean, (*viz.*) its own or the mutual Congress of other Bodies, to which, if we add the Gravity or direct Pressure of the Atmosphere, we need doubt of its Effects in all Mechanick, Hydrostatick or Hydraulick Motion; and that what the Ancients call'd *Fuga vacui*, some Moderns, Suction or Attraction, is really nothing less but Pulsion, or the external Pressure of Air.

THUS having begun this Chapter with the Etymology and Definition of Elasticity, I conclude it with such Propositions and Rules, as may from the universal Laws, just mention'd, explain the Velocity of each of the elastick Bodies, after Percussion, according to the learned *Wallis*, in his Treatise of *Resilition*, cap. 13. pag. 686, of his *Mechanicks*.

P R O P O S I T I O N I.

If an heavy Body in Motion strikes directly upon a fixt Point, whether one or both Bodies be elastick: It will rebound, or be struck back again, with the same Celerity with which it came, and by the same right Line.

FOR let A. be the heavy Body (whose Weight is m P, its Celerity r C, and so its *Momentum* $m r$ P C) which, by the right Line A A, strikes directly upon the fixt Point B. And let not either Body (whether it be the resisting or impelling one) be so perfectly hard, that it cannot any ways yield to the Stroke. Neither let it be so soft, that it may lose its first Figure by the Stroke (which usually happens in Wax, Lead, Clay, and other Bodies of such Sort, either fragile or ductile) but let (one or both Bodies) have its elastick Force, by which it may restore it self into its first Position, as soon as ever the compressing Force shall cease.

AND let the percuss'd Part of the impell'd Body be understood as press'd inward by the Force of the impelling Body, it will therefore by its native elastick Force endeavour to restore it self.

I say,

230 *An Introduction to a General System*

I say, first, That this Pressure will be so far continued, till the elastick Force, which opposes the Compression, counterpoises the compressing Force. For so long as the compressing Force is stronger than the Resistance of the elastick Body, it will always persevere to bend or compress the elastick Body.

BUT this compressing Force is double of the *Momentum* of the heavy impinging Body. For the Force brought by the heavy impinging Body, is equal to its own *Momentum* (in as much as its whole Motion is stopt) suppose $m r P C$. But also, because of the equal Resistance of the impelled Body, (which opposes the Compression as much as if an equal contrary Force met it) so there arises another $m r P C$; (but which must have a less Regard paid to it, in as much as it is occasioned some other way :) And therefore the whole compressive Force is, $2 m r P C$.

I say again, That the impelling or compressing Force, where the Matter is reduced to a Counterpoize, ceases, (in as much as it is wholly spent in impelling the elastick Body.) For the Force being outwardly impress'd, such as we suppose the impelling (otherwise than the natural Force, such as is its Gravity, and elastick Force compress'd) where once it is brought to a Quiescence, perishes; nor is able to restore it self: So that it can neither hasten it self, where it is retarded. For howsoever a Body in Motion, unless it may be hindered, perseveres in the very same: Yet it is not accelerated, or brought from Rest into Motion, without a positive Cause.

I say therefore, *Thirdly*, The impelling or compressing Motion (as is said) ceasing, that the elastick Force, now free, and (as is already demonstrated) being equal to the Force lately compressing, endeavouring equally on both Sides to explicate it self, spends half its Force, or one $m r P C$; upon the impell'd Body (howsoever with a vain Attempt) and the other $m r P C$ upon the impelling heavy Body. Which therefore the Body A repels with the same Force, and so likewise with the same Celerity, with which it was brought (to wit, by its Force $m r P C$ and so, because of its Weight $m P$, by its Celerity $r C$.) For an equal Force, being apply'd to the same Weight, moves with the same Celerity.

I say, *Lastly*, That it will be struck back again by the same right Line. For when an elastick Body is inwardly bent by a Body striking directly upon it, the same by its elastick Force restores it self to its first Figure, by *Def. 1.* of this Book, (and so returns by the same Way by which it was pressed,) it imparts the same Direction to the Body repercussed, which it received from thence, unless
that

of Hydrostaticks and Hydraulicks. 231

that it may be to contrary Parts. Which therefore will return by the same right Line.

AND, as is already demonstrated, the elastick Force, being placed on the impelled Body, it obtains as much as if that Force was in the striking Body, or even in both. For however that obtains, the impelling Force cannot be stopt before that the opposite Resistance of the elastick Body (whether single or double) counterpoizes; neither perseveres farther; from whence the rest follow.

The same another Way.

IF there was no elastick Body, the Motion A would be stopt, being reduced to Rest. The whole Motion therefore, which is afterwards, is from the restitutive Power of its elastick Body, and that is always equal to the Force of the Stroke. For the Force brought against the elastick Body, is equal to the Stroke (which it sustains) which therefore so far compresses the elastick Body, till its Resistance counterpoizes that. And indeed, if it was only meerly to resist, the impelling Body would be at Rest: But as an elastick Body resists, not as a meer Impediment, but as a contrary Force, and does indeed re-act as much as it is acted upon; and the Body acted upon being equal to the Stroke or impelled Force, the restitutive Force also counterpoizes the same (which in the following Propositions has no less Place, and so must be taken for a Demonstration.) But in this Case, supposing the Weight of the heavy Body A, to be $m P$, and its Celerity $r C$, the Greatness of the Stroke it produces is $2 m r P. C.$ as much therefore will be the restitutive Force of the elastick Body; which therefore endeavours on both Sides to explicate it self, and so one Half of its Force or $m r P. C.$ resisting against the impelled Body, however with a vain Attempt; and the other Half of its Force $m r P. C.$ against the impelling Body A. Upon account of the Weight $m P.$ its Celerity back again will be $r C.$ which was the Proposition.

AGAIN; as in all Probability there is no Body so firm as not to yield to the Percussion of another, tho' it may do it in so small a Degree as not to be perceiv'd, and upon that Account may be disregarded and esteem'd as nothing; and so the resisting Body may be held immoveable (as, *e g.* when a Fly or Gnat making a Skip upon the Earth strikes it) and if we conceive the thing after this Manner, we may again demonstrate what we are upon from the 8th Proposition of this Chapter (only changing the Order of the Proposition) for

232 *An Introduction to a General System*

for there A, a Body in Motion, is suppos'd to impinge against B, a Body at rest, and capable of being put into Motion: If we there suppose the Weight of A to be $m P$ (which must be suppos'd very small) and its Celerity $r C$; and the Weight of B to be $n P$ (which must be suppos'd very great) and at the same time at rest: Then the Celerity of the impingent Body A after Contact, will be $\frac{m-n}{m+n} r C$ forwards. (By Proposition eighth of this Chapter) that is according to the Prevalence of the Character—, for $n P$ is suppos'd much greater than $m P$,) $\frac{n-m}{m+n} r C$ backwards; which will be the same in this Case, as $\frac{n}{m} r C = r C$ backwards; and this proceeds from the small and trifling Magnitude of the Weight $m P$, compar'd with the vast one of the Weight $n P$. Moreover, the Velocity of the remaining heavy Body B, will be after Contact $\frac{2m}{m+n} r C$; which, considering the small and insignificant Ratio of m , or $2m$, to n , or its much smaller Proportion still to $m+n$, is hardly worth mentioning; so that the Body B may not improperly be said to be unmov'd. But if this will not be admitted, and the Obstacle B not be imagin'd perfectly immoveable; then its Fixedness shall be reckon'd equal to the quiescent Weight $n P$, which may be esteem'd as infinite, tho' it is not absolutely incapable of being mov'd; for there is no finite Body which may not be mov'd, unless hinder'd by some foreign Cause. (*Vid. Prop. 8th*) The Velocity therefore of the impingent Body A in its Rebound after Collision (*vid. Prop. the 8th*) $\frac{n-m}{m+n} r C$, will really be $\frac{\infty-m}{m+\infty} r C$; which is the same as $\frac{\infty}{\infty} r C = r C$, as appears from the infinitely small or no Proportion of the finite m to the finite ∞ . And the Velocity $\frac{2-m}{m+n} r C$ after Contact, of the quiescent Body B, will be $\frac{2m}{m+\infty} r C$, which is the same (by reason of the finite m , and the infinite n) as $\frac{2m}{\infty} r C$, or $\frac{0}{\infty} r C$, which is as no Velocity; and consequently B may be reckon'd not to move, as has been demonstrated elsewhere.

S C H O L I U M.

I am not ignorant that many place a sort of unintelligible mechanical Power, in some continued Motion supposed to be always existing, by

by which Power (if the Body happens to be stopp'd) only by a Change of the Direction it rebounds, without any new Cause: But as this is only said *gratis*, and is no more than a bare *Postulatum* (that a fresh Motion should be produced without any fresh Cause) and at the same time is to be urged with great Difficulties; so what chiefly convinces me of its Falsity, is, that as any Obstacle is of it self sufficient to diminish Motion, (so that a Body shall be hinder'd from proceeding forward by it) so there seems Occasion for some positive Power to effect the Contrary. And as this positive Power is readily found in elastick Force, I see no Reason why we should reject it; especially since we may observe, that from any soft or fluid Body impinging against a solid one, all Motion is entirely stopp'd, but no Rebound made at all.

BUT yet, if the Body be of such a Nature, that it be neither so soft as to have no elastick Power remaining in it, nor yet so very elastick, but it will allow some Change to be made in its Figure, without having all its elastick Fibres entirely broke; there will then be some Rebound made, tho' an imperfect one. (For 'tis all along supposed in the Demonstration, that the elastick Power is sufficient to bear the Shock of the impellent Body, without suffering a Fracture thereby.) Besides, we find that this happens in some Measure from the Resistance of the *Medium*; likewise, by which the Motion, whether direct or reflex, is sensibly diminished, as likewise from the natural Descent of heavy Bodies, whereby the Motion of one Body becomes blended with that of all others: But these Considerations, and all others of the like sort, we set aside as extrinick.

BUT it is to be observed, That however we suppose the impellent Force, as entirely owing to some extrinick Impression, and so wholly to cease when the impressed Body is reduc'd to an equal Degree of Resistance; yet it may be, that this Force may in some measure be natural, taking its Rise from the Principle of Gravity; as imagining the impelled Body projected downwards, or else descending with a constantly accelerated Motion, it may acquire that Force, with which it strikes against the Obstacle.

THE Force therefore extrinsically impressed, is to be separated from that which proceeds from the Principle of Gravity, simply considered; and the first may be wholly lost, while this remains, and shall so far lessen the elastick Force, that the Rebound shall be made more imperfect, and with less Velocity; nay, it may be proved so considerable, as to overcome the elastick Force to such a Degree, that altho' it may rebound (by reason of the external Impressi-

234 *An Introduction to a General System*

on being taken off, by which it was at first compress'd) yet it shall not be sufficient to drive the impacted Body from it.

BUT still, the Degree of Motion, which is acquired by Acceleration, is to be separated from that owing to its natural Gravity: For any accelerated heavy Body, if stopt by any Obstacle in its Progress, still retains its natural Gravity, tho' it loses its acquired Velocity; and thence forwards it begins to go on, as if just put into Motion, without any respect had to its former acquired Celerity, which is now lost.——But if it should be objected against this Hypothesis of elastick Power, that all hard Bodies whatever have this Property of Repercussion or Reflexion, and in a Degree always proportionate to their Hardness or Firmness; yet may this be very well accounted for, without any Danger to our Hypothesis of elastick Power. And this only by supposing all hard Bodies to be likewise elastick, which I see no Reason to deny. And altho' the harder they are, the less they give way to any Pressure; yet they do give Way something; and the less they give Way, the more forcibly they resist and repel. And altho' we consider Hardness separately from Elasticity, that we might the better demonstrate what would follow, if there was no elastick Power; yet do we not thereby design to deny an elastick Power in Bodies simply hard; since in all Likelihood there are no Bodies so simply hard, as to have no Elasticity: (Tho' there may be Bodies so soft as to have none.) And indeed, to speak the Truth, I fully believe, that either there are no hard Bodies, which are not elastick; or, if there are such, then upon their Congress, there follows no Rebound, but they observe the Laws laid down elsewhere. And that in Marble, Glass, Wood, Earthen Ware, and the harder Sort of Metals, there is an elastick Power, is plain not only from the Sound which we hear, (which is either more confus'd or distinct, as the Repercussion is slower or quicker) but from their remarkable Trembling, so plain both to the Sight and Touch.

P R O P O S I T I O N. II.

If an heavy Body in Motion strikes obliquely on an immovable Obstacle, and supposing one or both of them to be elastick, the Rebound will be with the same Celerity (in the same Plane) and in such a Manner, as to make the Angle of Reflection equal to the Angle of Incidence.

LET

LET there be supposed a heavy Body striking upon the fix'd Plane A B C, streight along the oblique Line O B, making the Angle of Incidence O B A. Let this oblique Motion thro' O B be consider'd as compounded of two Motions; one Parallel, as O P or A B, the other perpendicular as P B; the former of which (being a Parallel) strikes not at all against the Plane A B C, nor is at all impeded by it; so that it still continues to go on with the same Celerity it did at first; *i. e.* In the same Time it was carried from O A to P B, it will in equal Time be carried (an equal Length) from P B to Q C. But in the other Line (which is a perpendicular) it will strike directly upon the Plane A B C thro' the Line P B: And so, at the Point of Incidence B, it will be directly return'd thro' the Line B P, with the same Force, and consequently with the same Celerity, by Reason of its elastick Power; That is, it will be carried in the same, or in equal Time from A C to O Q, as it was from O Q to A C; that is again, in the same, as from P C to Q C: And so thro' the right Line B Q. And furthermore, by Reason O P is equal to P Q, and P B, or B P, being common to both; (and all of 'em run thro' in equal Times) the Triangle B P O will be equal to the Triangle B P Q (and both of them too in the same Plane, by Reason of the right Line O P Q.) So then the Angle P B Q is equal to the Angle P B O: And likewise the Angle P B Q is equal to the Angle P B O, and (the remaining Angle at the right one) Q B C, which is the Angle of Reflexion, is equal to (the other remaining Angle at the right one) C B A, which is the Angle of Incidence.

S C H O L I U M.

IF any young Beginner (or one who has made some Proficiency this Way) should ask, Why I affirm the direct and simple Motion, thro' the Line O B, to be compounded of two others; or, if I must have it compounded, since this might as reasonably be done a Thousand other Ways; why do I, omitting all the rest, without any Shew of Reason, prefer this Way to all others? (for I neither prove it to be compounded, or to be so no other Way but this). To these Queries I have this to answer, That there is no Motion whatsoever so simple, but is resolvable into many component ones; and as for my chusing this Way rather than any other, I use that Liberty I have of selecting out of several Compositions, that which serves my present Occasions best; nor need I prove, that this Compositi-

236 *An Introduction to a General System*

on alone is possible ; but 'tis enough to say, it is one out of many : And it is free for every Author, to chuse out among many Truths, that one which most conduces to his present Design.

AND (that I may illustrate this Affair by other Compositions) this Method obtains in other Cases, as well as the present one : For it is known, that the Number 12 is compounded of $3 + 4$, and $2 + 6$, and of $1 + 12$ (besides innumerable otherwise by broken Numbers). If therefore the Number 12 were given to be divided by the Divisor 2, and the Quotient should be ask'd : The Answer would be, That the Number 12 was compounded of $2 + 6$; therefore the Divisor 2 being taken, the Quotient will be 6. But if any one should pertinaciously suggest, that this Number 12, of which we are discoursing, is not at all made up of such a Composition, but by a bare Collection of Units only (just, for Instance, as a Collection of so many distinct Men would be). Why therefore should I, without any Proof, affirm a Number (form'd merely by Addition) to be a compound one, by multiplying it? And besides, if I must have it compounded by multiplying; why must I assert it to be compounded of 2×6 , when it may with equal Reason be said to be a Compound of 3×4 , or 1×12 ? Nor do I give any Proof why it is compounded that Way, rather than any other? Now, I say, would any one think such an Objector as this worth listening to? Does not any one presently see what would be the Answer; That the Number 12 is not at all the Less compounded of the Factors $2 + 6$, for its being form'd by Addition? For when a Number is once form'd, by whatever Way that be, it never upon that Account loses its proper Affections. And why I did not say that it was compounded of $3 + 4$, or $1 + 12$ (tho' all this, and much else, is very true) but only of $2 + 6$, is very easily accounted for, *viz.* by saying, that this Composition tended most to the Matter in hand, without denying all the others to be true too; for the Number sought for, was not one, which compounded of 1 or 3 or 4, would make 12, but that which would do it by 2.

IN like Manner, since the Ratio between A and B may be shewn a 1000 Ways; as for Instance, either from that of A to C, and C to B; or from that of A to D, and D to B, or from A to E, and E to B, &c. yet supposing the Ratios given between A and B (E. G. let it be that of 1 to 2) and likewise between A and C (suppose of 1 to 3); and it should be demanded, what is the Ratio of C to B: It may be answer'd, not that the Ratio of A to B is compounded of A to D, and D to B; or of A to E, and E to B (for those Compositions, however just, yet are not to the

the present Purpose) but of A to C, and C to B: And so, if from the Ratio of A to B (one of the Components) be found out that of A to C, then will the remaining one likewise of C to B, be found too, (suppose of 3 to 2.)

$$\frac{A}{B} = \frac{A}{C} + \frac{C}{B} = \frac{A}{D} + \frac{D}{B} = \frac{A}{E} + \frac{E}{B} \text{ \&c. } \frac{A}{C} \left(\frac{C}{B} \cdot \frac{1}{3} \right) \frac{1}{2} \left(\frac{3}{2} \right)$$

BUT if any one should demand, why I without any Proof affirm the most simple Ratio of 1 to 2, to be compounded: Or why just so compounded, when it might as well be done a 1000 other Ways; there is no Doubt to be made, but this is a very trifling and injudicious Question: Since no Ratio is so intirely simple, as not to be resolvable into many others: Nor need there be any other Reason given why I prefer this Composition to all others, but its being the properest for the present Subject.

IN the same Manner, if any one should demand the Velocity of a heavy Body, whose Momentum is supposed $m r P C$, and its Weight (*pondus*) $2 m P$. The Answer I would give, should not be $m r P C = m P \times r C$, or $= r P \times m C$ (which are all true, and proper enough in other Places, tho' not so here.) But I would say, $m r P C = 2 m P \times \frac{1}{2} r C$; and so the Velocity sought for, to be $\frac{1}{2} r C$: For the Question was not with what Celerity the Weight $m P$, or $r P$, but with what Celerity the Weight $2 m P$ must be carried to have its Momentum $m r P C$.

AND this is exactly applicable to our present Case. For since it is plain (which no one can deny) that the Motion O B is the same as that compounded of O P and P B; why then should not I say, that the Motion O B is compounded of O P and P B, or, which is the same, is resolvable into them? For the same Reason, as if, knowing the Number 12 to be the same with that Compounded of 3 + 4, I should say, the Numb 12 to be a Compound of 3 + 4? And altho' it may be compounded several other Ways, yet I chose this, as best suiting my present Design. As I might do likewise, if upon another Plane, I should choose another Composition: For if instead of the Plane A B C, I should take $\alpha B \gamma$; I should then say, that the same Motion O B was compounded of O π and πB , and not of O P and P B: And so by Reason O π and $\pi \chi$ being equal, in the same strait Parallel; and B π being the same or equal to πB , the Reflection would be in the right Line B χ ; and the Angle of Reflection $\chi B \gamma$, would be equal to the Angle of Incidence O B α .

I exhibit these Compositions (respectively) not upon Account of their being the only true ones, but chosen as the fittest for the Purpose in Hand: And here it may be proper to observe, that all that Part of the oblique Motion OB , which is oppos'd by the Plane ABC , or $\alpha B \gamma$, must be consider'd separate from that which is not so oppos'd; and this could no otherwise be done, but by resolving the oblique Motion into a Parallel and perpendicular one. And this is so clear, that no Illustration need have been given, if it had not been seriously objected against by one, no Novice in this Way.

P R O P O S I T I O N III.

If two heavy Bodies, equal to one another, meet each other directly, with equal Celerity; and supposing one or both to be elastick: Or if the Bodies are unequal, and their Celerities reciprocally proportional (so that their Momentums may at least be equal): One of them will be reflected with the same Celerity wherewith it struck, and in the same right Line.

THUS, let us suppose the two heavy Bodies A, B , meeting one another according to these Rules: And let the Weight of both be $m P$, and their Celerity $r C$; or let the Weight of that be $m P$, and its Celerity $r C$; and the Weight of this $r P$, and its Celerity $m C$; so that in either Case, the Momentum of either of them may be $m r P C$, and so of both taken together, $2 m r P C$. And since the elastick Power (whether single or double) of both of them, must sustain a Shock, and will continue to be bent inward, till its Resistance becomes equipollent to that of both the Bodies, and then the impellent Force (being by this Means reduc'd to rest, and so quite lost) ceases to act. Then the elastick Principle, by its own Force, (supposed equal to that of the impellent Bodies) endeavours to free itself equally on either Side, and so repels the heavy Bodies on either Side with the same Force $m r P C$ (the Half of the whole) *i. e.* with the same Force with which they came together, and so with the same Celerity respectively: That is, supposing the Weight on both Parts to be $m P$, with the Celerity on either Side $r C$, (but only different in Directions): But if their Weights be different, the Weight $m P$ will be repell'd with the Celerity $r C$, and the Weight $r P$ with the Celerity $m C$; (because $m r P C = m P \times r C = r P \times m C$.) *i. e.* either of them with the same Celerity with which it came. And this Return will be in the same
right

right Line (only by opposite Motions) because the elastick Power endeavours to recover itself in the same Direction it was press'd, by its striving to restore its former Figure ; which is to be understood in all the subsequent Propositions ; and so may there be taken for demonstrated.

This Proposition another Way.

IF there was no elastick Power, both the Bodies would stop and be at Rest ; and consequently, the whole of the Motion which follows proceeds from the restitutive Principle of the Elasticity, which is always proportionable to the Force of the Shock ; in this present Case, it will be $2 m r P C$; which being divided by an equal Endeavour on both Bodies to free itself, acts on either Side as $m r P C$; and so repels the Weight $m P$ with the Celerity $r C$, and the Weight $r P$ with the Celerity $m C$ as before.

P R O P O S I T I O N IV.

If two elastick Bodies (not compress'd together) are both suppos'd at Rest ; or both of them are carried with equal Velocity in the same right Line towards the same Place, or the Antecedent be carried with greater Velocity ; (whether they are contiguous or disjoin'd) there will then be no Impulse, or Compression of the elastick Force ; and consequently no Change of Motions.

AND therefore, if in heavy Bodies otherwise mov'd, a Celerity common to both be either added or subtracted therefrom, thence follows no Change of Impulse ; (or any of those things which happen from such a Change). But every thing is the same (as to the Impulse or Compression of the elastick Power) whether that common Velocity be there or not.

THIS Proposition is very evident, for if both the Bodies are at Rest, no Shock is given to either, no Motion obstructed, neither impells the other, and consequently there is no Compression of the elastick Power, which proceeds from Impulse, nor any Change of Motions from either (whether as to the Celerity, or Direction) let the Bodies be never so nigh, much less if they are disjoin'd. And this in like Manner would be the Case, if the Bodies are carried towards the same Place with the same Celerity : For if at setting out they are disjoin'd, they will always remain so, and at the
same

same Distance too from each other, by reason of the same Celerity in both; so that they cannot so much as mutually touch each other, much less impel. And if they are supposed contiguous; yet while the Body before flies with the same Celerity, with which the hinder one follows, there cannot possibly be any Shock given, nor any Obstruction; (and consequently there will be no Impulse, no Compression, nor any Change) of Motion. But if the Velocity of the antecedent Body be greater than the others, it will be so far from being press'd by the tardy one behind, that this will still lose Ground; and tho' they were contiguous at first, there will now be some Distance between; and if there was a Distance at first, this will still be encreas'd. Yet I add, *so that they be not mutually compressed together*: For if this happens, the elastick Force will then exert it self, as soon as possible, and so make some Change of Motion.

AND for the same Reason, the Corollary also is plain: For in Proportion to the Celerity, with which the antecedent Body flies forward, and withdrawing it self declines the Blow, will its Non-Resistance be to the following one, and the Obstruction of its Motion, from whence arises the Impulse and Compression (not greater than when the antecedent Body withdraws it self from the following contiguous one;) but the whole impulsive or compressive Force must be estimated from the Excess of the Celerity of the following Body above that of the antecedent one, moving towards the same Place; which, however great it be (or whatever Motion is added or subtracted) is common to both.

This demonstrated another Way.

THUS, by Reason of the common Motion of both Bodies, there is no Collision made, or at least, no Change of the Collision. And therefore no Compression of the elastick Power (or of what follows from thence) to be equipollent to the Shock.

P R O P O S I T I O N V.

Let an heavy Body in Motion strike directly against an equal Body at Rest, (but not hinder'd from Motion,) and let one or both of them be elastick; then the Body in Motion shall remain at Rest, and the quiescent Body shall proceed with the same Velocity which the first moving Body had.

LET

of Hydrostaticks and Hydraulicks. 241

LET the Weight of both these equal Bodies A, B (*Fig. 1. Tab. Seq.*) be $m P$. Let B be supposed at Rest, and A to strike directly against it with the Celerity $r C$; *i. e.* with the *Momentum* or Force $m r P C = m P \times r C$. By this Means a Force equipollent to this would be impress'd upon the elastick Power, by the Body A (stripping it self of the same) by which (if retain'd) the elastick Power would repel the Body A (being reduc'd to Rest) supposing B to be immovable, (not to mention what is return'd from one Obstacle to another): But by Reason of the unimpeded Body's B's giving Way, the elastick Principle gives the same Force to the yielding Body B, which it receiv'd from A (and does not retain it in itself as in the Case, *Prop. 1.* by which Means it might afterwards repel the Body A.) From whence it happens, that the impellent Body A (being depriv'd of all its Force, which it had spent on the elastick Principle) becomes quiescent; and the Body B is propell'd with the Force $m r P C$ (given to it by Means of the elastick Principle.) And so, by Reason of the Weight $m P$, is carried forwards with the Celerity $r C$, which was that of the impellent Body.

Another Demonstration of this.

LET there be two equally heavy Bodies, and the Weight of each be $m P$: Let the Body A strike directly against the quiescent Body B, with the Celerity $r C$, and so with the Momentum or Force $m r P C$. By which Means, by the yielding of the unimpeded Body B, they would jointly be carried, if there was no elastick Power, with the half Celerity $\frac{1}{2} r C$ forwards; because $m r P C = 2 m P \times \frac{1}{2} r C$. But by Reason of the elastick Power, a restitutive Force is impress'd upon the elastick Principle equipollent to $m r P C$ (for as long as the bending of the elastick Power is easilier effected than the Process of the heavy Body; that Power will be bent; and with the same Force with which it is bent, will it, by Reason of its Springyness, recover itself again. The elastick Power therefore, endeavouring to explicate itself on every Side, (the Weight of both Bodies being subtracted) repels the Body A, with the Force $\frac{1}{2} m r P C$; and with the same Force $\frac{1}{2} m r P C$ propels the Body B. that is, (by Reason of the Weight, on either Side, $m P$,) the Body A backwards with the Celerity $-\frac{1}{2} r C$, and B forwards with the Celerity $+\frac{1}{2} r C$. But A was to be carried, under another Denomination, (as has been observ'd) with the Celerity $+\frac{1}{2} r C$, forwards; therefore, as by this Means there is added the Celerity $-\frac{1}{2} r C$, backwards, A will remain at Rest (or which is the same, will

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242 *An Introduction to a General System*

not be mov'd with any Celerity towards either Part) by Reason $+\frac{1}{2}rC - \frac{1}{2}rC = 0C$. The Body B also was to be mov'd under another Denomination, (as has been shewn) with the Celerity $\frac{1}{2}rC$, forwards; but by this Means it is also propell'd with the Celerity $\frac{1}{2}rC$, forwards; therefore the whole Celerity is $\frac{1}{2}rC + \frac{1}{2}rC = rC$, forwards; *i. e.* the same which belong'd to the first mov'd Body A.

Or thus in a shorter Way.

EVERY Thing suppos'd as before; both the Bodies would be carried forwards with the Celerity $\frac{1}{2}rC$, if there was no Elasticity; and so both with the Momentum or Force $\frac{1}{2}m r P C$; the Greatness of the Shock is $m r P C$; and then the restitutive Force of the Elasticity, being equal to this, by endeavouring to free itself on all Sides, repels the Body A with half its Force, and with the other Half propel's the Body B; so that it communicates to A the Force $-\frac{1}{2}m r P C$, backwards; and to B, the Force $+\frac{1}{2}m r P C$, forwards; which respectively added to what had been laid down before; the Force upon A will be $\frac{1}{2}m r P C - \frac{1}{2}m r P C = 0 P C$, which therefore will remain at Rest; and the Force upon B will be $\frac{1}{2}m r P C + \frac{1}{2}m r P C = m r P C$, forwards; which therefore, (upon Account of the Weight $m P$) will be carried forwards with the Celerity rC , which was that of A.

Another Demonstration.

LET the two heavy Bodies A, B, be suppos'd equal, as before; and let A strike directly against B at rest, with the Celerity rC forwards. Let there be suppos'd also to be superadded to both, a common Motion, with the Celerity $-\frac{1}{2}rC$, backwards; by which Means the Celerity of A will be $rC - \frac{1}{2}rC = \frac{1}{2}rC$, forwards; and the Celerity of B will be $-\frac{1}{2}rC$, backwards: In which Case, the Body A, after Congress, will be carried with the Celerity $-\frac{1}{2}rC$, backwards; and B with the Celerity $+\frac{1}{2}rC$, forwards: But, (by Reason of the common Motion, which is as nothing, as far as it respects the Impulse) there will be the same Effect of the Impulse in the present Case: If therefore they be restor'd to their former State, by taking away on both Sides the Celerity which was added $-\frac{1}{2}rC$ (or which comes to the same Thing, by adding the Celerity $+\frac{1}{2}rC$, forwards) then will the Celerity of the Body B be found $-\frac{1}{2}rC + \frac{1}{2}rC = 0C$; and the

the Celerity of B to be $+\frac{1}{2}rC + \frac{1}{2}rC = rC$. That is, A will remain at Rest, and B will be carried forwards with the Celerity that before belonged to A.

S C H O L I U M.

I have here collected several Demonstrations (as I have done the same in other Propositions) not that I distrust the Force of any single one (or would be suppos'd willing to supply Want of Reason by Redundancy of Numbers) for every one, I think, carries its own Evidence; but I did it to suit the different Tastes of different Readers, who sometimes prefer one Method of Demonstration to another: The first indeed, and second do more clearly explain the physical Cause of the Thing, which yet I prosecute more sparingly in the following ones, as what depends upon these. And the last but one (taken from a Consideration of the Force, if there had been no Elasticity, and of the restitutive Force of the Elasticity, always equal to the Impression) are the best accommodated to my Hypotheses, and are, if I mistake not, true Geometrical Demonstrations. I have likewise added the last for the Sake of those who do not so readily assent to those Hypotheses of mine (which as yet are not generally receiv'd) for by this Method (which as well as the other I likewise accommodate to the following Propositions) which, setting aside all others, draws the following Proposition by a just Calculus, only from admitting *Prop* 3. and 4. of this Chapter, (which others, rather than endeavour to prove them, esteem as Postulatums, as evident in themselves, and prov'd by physical Experiments). By this Method, I say, it happens, that whatever Doubt there be of those Hypotheses, which yet I take as mighty just and true, yet is there no Room left to doubt of the Truth of the Propositions; which depends no otherwise upon my Hypotheses, than that I from thence prove the third Proposition of this Chapter, which others esteem, without any Proof, a Postulatum. And I likewise thought it not at all an improper Undertaking, to shew the Consent of each Method: So that the Phænomena of Motion in our Hypotheses (altho' deduc'd from other Principles, and the Hypothesis itself, afterwards publish'd in the philosophical Transactions, was first exhibited to the Royal Society, and inserted in their Registers, before either of the others were made publick or exhibited) are plainly the same with the Phænomena of the Hypothesis of our own Countryman the late Sir *Christopher Wrenn*, and the Dutchman *Christian Hugen*s. But still there is this Difference between them;

244 *An Introduction to a General System*

that what they demanded as Postulatus, or infer from Observations, wherein no Regard was had to the Principle of Elasticity; we, by Means of this Principle, deduce from first Principles, while at the same Time, the Phænomena which we collect from thence by Reasoning, proceed upon the same Foundation theirs do, viz. from approv'd Experiments which they had observ'd. So that upon that Account there would be less Occasion to doubt of the Truth of our Consent in these Appearances, since each of us, without the Knowledge of the other, upon different Principles, and by different Methods, arriv'd at the same Phænomena.

PROPOSITION VI.

If two elastick Bodies, equal to each other, are carried in the same right Line towards the same Part, by unequal Celerities; and the hindermost one, being carried with the greater Celerity, strikes directly against the antecedent one; after Impulse, they shall be both carried in the same Direction, but with interchang'd Velocities.

LET the Weight of both these equal Bodies A and B be $m P$; let the Velocity of A be $r C = s C + t C$; and of B, $s C$: So that the Momentum of A will be $m r P C$, and of B, $m s P C$, both forwards; upon which Account the restitutive Force of the elastick Principle (being always equal to the Shock) will be $m r P C - m s P C = m t P C$; which by attempting equally on all Sides to disengage itself, will, with the one Half of its Force $\frac{1}{2} m t P C$, repel A, and with the other urge forwards B. So by Reason of the common Weight $m P$, it communicates to A the Celerity $-\frac{1}{2} t C = -\frac{r-s}{2} C$, backwards, and to B the Celerity $+\frac{1}{2} t C = +\frac{r-s}{2} C$ forwards. But if otherwise, there was no Elasticity, then both would be carried with the Velocity $\frac{r+s}{2} C$; which being added on both Sides, the Celerity of A will then be $-\frac{r-s}{2} C + \frac{r+s}{2} C = s C$; and of B $+\frac{r-s}{2} C + \frac{r+s}{2} C = r C$; that is, both will proceed forwards, with interchang'd Velocities.

Another Demonstration of this.

LET the two equal Bodies be A, B (*Fig. 3. Tab. Seq.*) and let the Celerity of the antecedent one B, be $s C$, and of the hinder Body A, let the Celerity (which must here be suppos'd the greater of the two) be

be $rC = sC + tC$. Since then the Celerity sC is common to both, 'tis the same in Effect (as to the Compression of either) as if it was supposed to be taken away on both Sides. Therefore the hinder Body A, will strike upon the quiescent one B, with the Excess of its Celerity tC . In which Case B, after Collision, will be driven forwards with the Celerity tC , which was that of the following one A; and A, as if now at Rest, with the Celerity oC : If then the common Celerity sC (just now suppos'd taken away) be again restor'd to both, then will the Celerity of A be found to be $oC + sC = sC$; and the Celerity of B $tC + sC = rC$: that is, both will be continued in the same Direction, with interchang'd Velocities.

PROPOSITION VII.

If two elastick Bodies equal to each other, (being carried to opposite Parts in the same right Line) directly meet each other with unequal Celerities; after Collision they shall be return'd to contrary Parts, with interchang'd Celerities.

LET the Weight of both the Bodies, A, B, (*Fig. 4. Tab. Seq.*) be mP , and the Celerity of A be rC , forwards, and of B $-sC$, backwards; and let $r + s = z$. The Momentum of A shall be $+m r P C$; and of B, $-m s P C$: Therefore the restitutive Force (equal to the Blow) of the elastick Principle (which sustains both) will be $m r P C + m s P C = m z P C$; which endeavouring to disengage itself on both Sides, with the Half of its Force $\frac{1}{2} m z P C$ repels both the Bodies; and therefore, by Reason of the common Weight mP , gives to A the Celerity $-\frac{1}{2} z C = -\frac{r+s}{2} C$, backwards; and to B the Celerity $+\frac{1}{2} z C = +\frac{r+s}{2} C$, forwards. But if there was no Elasticity, then they would both be carried with the Celerity $\frac{r-s}{2} C$; which added on both Parts, will make the Celerity of A to be $-\frac{r+s}{2} C + \frac{r-s}{2} C = -sC$, backwards; and of B to be $+\frac{r+s}{2} C + \frac{r-s}{2} C = +rC$, forwards; that is, to opposite Parts, with interchang'd Celerities.

Another

Another Demonstration.

LET the Celerity of A be $r C = s C + t C$, forwards; and of B, supposed equal to A, let the Celerity be $-s C$, backwards; and these two Bodies to meet each other directly. As then the Celerity common to both is $s C$, but to different Parts: Accordingly after Collision, (by Reason of these Celerities) A will be carried with the Celerity $-s C$, backwards; and B, with that of $+s C$, forwards: But let these Celerities be supposed taken away, then there will be left to the Body A the Celerity $t C$, with which it struck the quiescent Body B; and, upon Account of this Celerity, the Body B will be carried forwards with the Celerity $t C$, and A (now quiescent) with the Celerity $o C$; which, if respectively added to those before mention'd, then will the Celerity of A be $-s C + o C = -s C$, backwards; and of B, $+s C + t C = +r C$, forwards; that is, to contrary Sides, with interchanged Celerities.

Another Demonstration of this.

LET there be supposed two Bodies A B, which meet one another directly; A with the Celerity $r C = s C + t C$, forwards; and B with the Celerity $-s C$, backwards. Let there also be given to both, (by a common Motion) the Celerity $+s C$, forwards; by which Means the Celerity of A will become $r C + s C$, forwards; and of B $-s C + s C = o C$: (that A may be carried with the Celerity $r C + s C$ towards B as quiescent) which being suppos'd; the Celerity then of A, after Collision, will be $o C$; and of B $r C + s C$, forwards: And the same likewise will happen, in the Case propounded (as far as regards the Impulse). If therefore the Celerity $+s C$ (which was added) should be taken away on both Sides, then will the Celerity of A be found to be $o C - s C = -s C$, backwards; and of B to be $r C + s C - s C = r C$, forwards; that is, they will be carried to opposite Parts, with interchang'd Velocities.

P R O P O S I T I O N VIII.

If a heavy Body in the Motion, either strikes directly against a Quiescent one (either equal or unequal to it) with any given Velocity; (and let one or both of them be suppos'd elastick) the Celerity

rity then of the impingent Body, after Collision, shall be to the Celerity it had before, as the Difference of Weights to their Sums; and this will be either backwards or forwards, according as the Weight of the impingent Body is less or greater than that of the Quiescent one; and if both are equal, then will it remain at these. The Celerity likewise of the Body at Rest, (after Collision) will be to that of the impingent one, as double the Weight of the Impingent, to the same Sums of their Weights; and therefore, supposing their Weights equal, its Celerity will be that of the first mov'd Body.

LET the Weight of the Body A in Motion be $m P$, and its Celerity $r C$, and its Momentum consequently $m r P C$: And let the Weight of the Body at Rest (which A strikes directly against) be $n P$; Then will the restitutive Force (always equal to the Shock) of the Elasticity be $\frac{2 m n}{m + n} r P C$, which, by attempting to free itself equally on all Sides, will, with the one Half $\frac{m n}{m + n} r P C$ of its Celerity, repel A, and with the other drive forwards B; and consequently gives to that (on Account of the Weight $m P$) the Celerity $-\frac{n}{m + n} r C$, backwards; and to this (by Reason of the Weight $n P$) the Celerity $+\frac{m}{m + n} r C$, forwards: But, on the other Hand (supposing the Elasticity away) they would then be both carried with the common Celerity $\frac{m}{m + n} r C$, forwards, which, if added on both Sides, then will the Celerity of A be found to be $-\frac{n}{m + n} r C + \frac{m}{m + n} r C = \frac{m - n}{m + n} r C$, either forwards or backwards, according as m or n is largest; or else none at all, if these are equal, because $m - n = 0$: and the Celerity of B will be $+\frac{m}{m + n} r C + \frac{m}{m + n} r C = \frac{2 m}{m + n} r C$; and if $m = n$, with the Celerity $r C$. Which was to be demonstrated.

Another Demonstration.

LET the Weight of A be $m P$, and the Weight of B be $n P$; and let A be supposed to strike directly against B, with the Celerity $r C$; let this Celerity also $r C$ be supposed to be divided in Parts,
reci-

248 *An Introduction to a General System*

reciprocally proportional to the Weights, viz. into $\frac{n}{m+n} r C$, which may answer to the Weight $m P$, and into $\frac{m}{m+n} r C$, which may answer to the Weight $n P$. And further, let the Celerity $\frac{m}{m+n} r C$ (which belongs to B) be taken away on both Sides, or, which is much the same, added to the Motion backwards; (which common Addition or Subduction of Impulse makes no Difference in our Account) then will the Celerity of A be $r C - \frac{m}{m+n} r C = \frac{n}{m+n} r C$; and of B, $0 C - \frac{m}{m+n} r C = -\frac{m}{m+n} r C$, which are in a reciprocal Proportion to the Weights: Therefore they will both be return'd back with the same Celerities they approach'd; that is, A with the Celerity $-\frac{n}{m+n} r C$, backwards, and B with the Celerity $+\frac{m}{m+n} r C$, forwards, and the same will be the Ratio of the Impulse in the Present Case: And therefore, if the Celerity $\frac{m}{m+n} r C$ forwards, be restor'd on both Sides, (which was just now taken away) then will the future Celerity of A be found to be $-\frac{n}{m+n} r C + \frac{m}{m+n} r C = \frac{m-m}{m+n} r C$; which will be either forwards or backwards, as m or n shall be greatest (or else neither Way, if they are equal). And the Celerity of B will be $\frac{m}{m+n} r C + \frac{m}{m+n} r C = \frac{2m}{m+n} r C$, forwards, as before.

P R O P O S I T I O N IX.

If two elastick Bodies, either equal or unequal, be carried in the same right Line towards the same Place, with any given Velocities (tho' suppos'd such, as that the following Body, carried with the greater Velocity of the two, shall strike directly against the antecedent one). Then after Collision, they shall be both carried with the same Velocities, towards the same Parts; as will appear from the present Calculus.

LET

of Hydrostaticks and Hydraulicks. 249

LET the Weight of the antecedent Body B be n P, and its Celerity s C forwards; let the Weight of the following one A be m P, and its Celerity (greater than the other's) r C = s C + t C: The restitutive Force (being always equal to the Shock) of the Elasticity will then be $\frac{2 m n}{m + n} t$ P C; which endeavouring equally on both Sides to explicate itself, will exert on both Sides its half Force $\frac{m n}{m + n} t$ P C; and so give to A, by reason of the Weight m P, the Celerity $-\frac{n}{m + n} t$ C, backwards; and to B, by reason of its Weight n P, the Celerity $+\frac{m}{m + n} t$ C, forwards: But then (supposing no Elasticity) they would be carried with the common Celerity $\frac{m r + n s}{m + n}$ C; which if added on either Side, will give the future Celerity of A $-\frac{n}{m + n} t$ C + $\frac{m r + n s}{m + n}$ C = $\frac{m r + n s - n t}{m + n}$ C = $\frac{m r - n r + 2 n s}{m + n}$ C; which will be either forwards or backwards, according as the Sign + or - prevails, and consequently neither Way, if they are equal; and the Celerity of B will be $\frac{m}{m + n} t$ C + $\frac{m r + n s}{m + n}$ C = $\frac{m t + m r + n s}{m + n}$ C = $\frac{2 m r - m s + n s}{m + n}$ C, forwards. Q. E. D.

Another Demonstration of this.

LET the Weight of A be m P; and of B, n P, and let both be carried in the same right Line towards the same Place; suppose both forwards, and B with the Celerity s C; and A with the greater Celerity r C = s C + t C; and to strike directly against B. Suppose also, by a common Motion, the Celerity s C to be taken from both; (which, as it is common to both, will make no Alteration in the Impulse.) By which Means B will be reduc'd to rest, (by reason s C - s C = 0 C;) and A will strike directly against it with the Celerity r C - s C = t C. In which Case, A, after Collision, will be carried with the Celerity $\frac{m - n}{m + n} t$ C; (either forwards or backwards, as m or n shall prevail) and B with the

250 *An Introduction to a General System*

the Celerity $\frac{2m}{m+n} t C$, forwards. As therefore the Reason (Ratio) is the same in the present Case (as far as regards the Impulse) if the Celerity $s C$ forwards be again restor'd on both Sides, (which was before suppos'd taken away) then the future Celerity of A will be $\frac{m-n}{m+n} t C + s C = \frac{m t + m s - n t + n s}{m+n}$
 $C = \frac{m r - n r + 2 n s}{m+n} C$; (which will be either backwards or forwards, according as the Sign $+$ or $-$ prevails; and consequently neither Way, if they are equal). And the Celerity of B will be $\frac{2m}{m+n} t C + s C = \frac{2 m t + m s + n s}{m+n} C = \frac{2 m r - m s + n s}{m+n} C$ forwards, as before.

P R O P O S I T I O N X. and last.

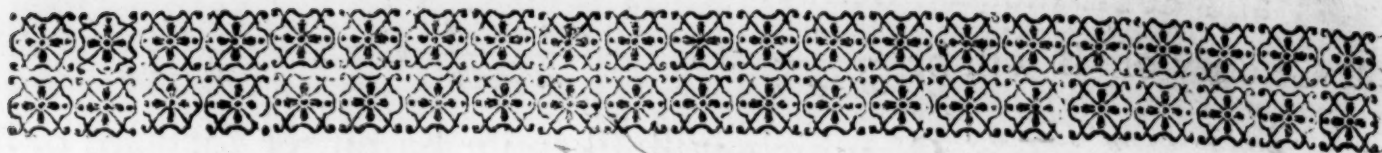
If two elastick Bodies, either equal or unequal, directly meet each other in the same right Line, with any given Celerities, they will both, after Collision, be carried with the same Celerities, and to the same Place; as will appear from the Calculation.

LET the Weight of A be $m P$, its Celerity $+ r C$, forwards; let the Weight of B, directly meeting A, be $n P$, and its Celerity $- s C$, backwards: And let $r + s = z$, the restitutive Force (being always equal to the Blow) will then be $\frac{2 m n}{m+n} z P C$; which endeavouring to disengage it self, will equally divide its half Force $\frac{m n}{m+n} z P C$; and consequently will give to A, by reason of its Weight $m P$, the Celerity $-\frac{n}{m+n} z C$, backwards. And to B, by reason of its Weight $n P$, the Celerity $+\frac{m}{m+n} z C$, forwards. But on the other Hand, if there was no Elasticity, they would then both be carried with the Celerity $\frac{m r - n s}{m+n} C$; which therefore added on both Sides, will make the future Celerity of A to be $-\frac{n}{m+n} z C + \frac{m r - n s}{m+n} C = \frac{m r - n z - n s}{m+n} C = \frac{m r - n r - 2 n s}{m+n} C$; which will be
either

either forwards or backwards, according as the Sign $+$ or $-$ prevails; and consequently neither Way, if they prove equal. And the Celerity of B will be $\frac{m}{m+n} \approx C + \frac{mr - ns}{m+n} C = \frac{mr + mz - ns}{m+n}$
 $C = \frac{2mr + ms - ns}{m+n} C$, which will likewise be either forward or backward, as the Sign $+$ or $-$ prevails; and neither Way, if both prove equal. Q. E. D.

Another Demonstration.

LET the Weight of A be m P; and of B, n P; which are to meet one another directly: A with the Celerity r C forwards; and B with the Celerity $-s$ C, backwards; and let $r + s = z$. Let there be suppos'd likewise (by some common Motion, (which therefore will make no Difference as to Impulse) to be added to both the Celerity $+s$ C, forwards; by which Means B will be reduced to rest, (because $-sC + sC = 0C$;) and A will strike upon it as at rest with the Celerity $rC + sC = zC$. In which Case, A, after Collifion, will be carried with the Celerity $\frac{m-n}{m+n} \approx C$; and B, with the Celerity $\frac{2m}{m+n} \approx C$. So that now taking away the Celerity s C from both Parts, which was just added, the future Celerity of A will be found to be $\frac{m-n}{m+n} \approx C - sC = \frac{mz - ms - nz - ns}{m+n} C = \frac{mr - nr - 2ns}{m+n}$
 C ; which will be either forwards or backwards, as the Sign $+$ or $-$ prevails; and neither of them, if they be equal. And the Celerity of B will be $\frac{2m}{m+n} \approx C - sC = \frac{2mz - ms - ns}{m+n} C = \frac{2mn + ms - ns}{m+n}$
 C ; which will likewise be either backwards or forwards, according to the Prevalence of the Sign $+$ or $-$; or neither Way, if they prove equal. Q. E. D.



B O O K. II.

C H A P. XIII.

Of the Impulsive Force of Air and other Fluids, in Hydrostaticks.

ITHERTO we have discours'd of the Equilibrium of Fluids by their Gravity or Weight, and by their Elasticity or Spring, but there is also an Equilibrium of Fluids which is, as it were, a Compound of both the other two; namely, by their Impulse.

FLAME, as the very curious and ingenious *Mariotte* observes, can make an Equilibrium with other Weights, by its Impulse. But as it is very rarely made use of to work Engines, any other than to rarify the Air in Pipes of Force, it is not necessary to examine in this Place, nor compare it, with other Fluids.

Now as the Demonstration of this Impulse, and the Equilibrium it makes with other Bodies, depends upon the Descent of those Bodies, which are either accelerated or retarded according to the Height or Depth of the Place from whence they proceed; and whether they ascend or descend: So consequently an accelerated Motion is that whose *Celerity or Velocity becomes greater every Moment*, and which is the Consequence of a Body that falls in open Air, occasion'd by the Impulse of the superincumbent Fluid, as Air, Water, and the like; and a retarded Motion is that *whose Velocity is diminished every Moment*, by rising upwards in the same Ratio as the other is accelerated by falling downwards; and this is called the free Descent of a heavy Body; by which we here understand the Fall of that Body in open Air, when it meets with no other Body, to oppose its Motion; in which it is generally observed, that a Body (as before hinted) which falls freely in the Air, acquires in equal Moments of
Time,

of Hydrostaticks and Hydraulicks. 253

Time, equal Degrees of Velocity, and that the Spaces through which the Body goes, encrease each Moment or Instant of Time according to the Series of the first uneven Numbers, 1, 3, 5, 7, 9, &c. which are the Differences of the Squares 1, 4, 9, 16, 25, &c. of the arithmetically proportional Numbers 1, 2, 3, 4, 5, &c. and that consequently the Spaces which Bodies go through from the Beginning of their Fall, are in a duplicate Ratio, or as the Squares of the Times or Moments; and it is only by Experience, that we can account for this Proportion, which will be as a Foundation for the greatest part of what we shall hereafter say.

P R O P O S I T I O N I.

The Space which a heavy Body goes through in a determinate Time being known, to find out what Space it will go through in a given Time.

SUPPOSE a Body to have descended twenty four Foot in one Minute of Time, to find how far the same Body will fall in the same Medium in three Minutes, for Example to the Numbers 1 : 9 :: 24; the two first of which, (*viz.*) 1, 9, are the Squares of the given Times, one Minute and three Minutes; and the third, *viz.* 24. is the Space gone through in the first Time: But to this you are to find a fourth Proportional. Which is done thus:

IF 1 : requires 9, what will 24 require?

Multiply 9

gives 216

To invert the last Proposition, let us propose the next.

P R O P O S I T I O N II.

The Time being known in which a heavy Body descends through a determinate Space, to find in how long Time it will descend through a given Space.

SUPPOSE a Body has spent one Minute in falling 24 Feet, to find what Time it will spend in falling, for instance, 216 Feet, in the same Medium.

SAY,

254 *An Introduction to a General System*

SAY, as 24 is to 216, so is 1 to the Square of the fourth Proportional requir'd.

$$\begin{array}{r} 24 : 216 . 1 \\ \quad \quad \quad 1 \\ 24) 216 (9 \\ \quad 216 \\ \hline \quad \quad 0 \end{array}$$

So that it appears the Number sought for, is 9, the Square whereof is 3.

THIS being premis'd concerning the Calculation of descending Bodies, as Fluids, and the like, by their Impulse, or the superincumbent Weight of its own or other Bodies gravitating upon them; and it being manifest that an inferior Fluid is press'd by a superior, and that equally every Way, because Action is equal to Re-action, and endeavours to recede every Way equally; and because Air and Water are the chief of the Fluids that are applied to the moving of Engines or Machines, for elevating of Water, and driving of Mills; it will be requisite in the next Place to shew how they make an Equilibrium with each other, and how they strike against and impel other Bodies, as we have it so well describ'd by *Marriotte*, Discourse 3. p. 116. of his *Hydrostaticks*.

Jet's d' Eau (says he) *Spouts or Streams of Water do not impel with the united Force of all their Parts, as solid Bodies do.* Let A B, Fig. 5. Tab. Seq. be a Spout of Water issuing from the Cylinder C D, and I C F is a Cylinder of Wood, whose Parts being joined together, 'tis evident, that when the Extremity F of this Cylinder strikes against a Body, it impels it with the united Force of all its Parts: But a Spout or Stream A B, being carried according to the Direction A d B, can only act by those Parts that go first; for Water being a Fluid, and compos'd, as it were, of an infinite Number of Corpuscles, or little Bodies, that slide one upon another, as small Grains of Sand would do; only the first towards B can make the first Effort upon Bodies that they meet, and they either reflect or fall off before the other Parts at d can impel in their turn.

FOR the better understanding of this, you must consider that the Velocity of Water going out at a small Hole made at the Bottom of a very large Tube, is very different from the Velocity of that which issues from a Tube whose Diameter is equal throughout; for if in this latter Case it begins to go out very slowly, just as a Cylinder of Ice would do, that you should let fall.

EXPER. 2. *Fig. 6. Tab. seq.* Let A B be a Tube of equal Breadth, fill'd with Water, and sustain'd with the Finger at B; 'tis evident that the Velocity of the Water when it goes out at B, is equal to that at A, and the whole Cylinder of Water falls at once, as if it were solid; and consequently to the same Rules in falling, that a Cylinder of Ice of the same Bulk would be; namely, that beginning by a very small Degree of Velocity, it encreases in its Descent, according to the uneven Numbers 1, 3, 5, 7, &c. that is to say, if in one Quarter of a Second it falls a Foot, the second Quarter it will fall three Foot, in a third, five, and so on; from whence it follows, that the Water which was at A, being got to B, will go out much faster than that which goes out first.

Galileo (says our Author) has spoken very largely of this Acceleration of the Velocity of Bodies that fall freely in the open Air, which may be thus conceiv'd; suppose a very light Body to strike against another an Hundred times heavier than it self, it will give the hundredth part of its Velocity, and striking it a second time, it will give another hundredth Part; so that if the impelling Body has an Hundred and one Degrees of Velocity, the impell'd Body will take one Degree at the first Impulse, and its Quantity of Motion will be an Hundred; and being impell'd a second time by the light Body, with the same Velocity of an Hundred and one Degrees, it will receive from it a new Degree of Velocity; which join'd to the first, will make two Degrees: The third Impulse will still add a Degree, and so on, the same thing will happen, if a weak Power draws a very heavy one to it, by acting upon it successively. Now whether a Body be attracted or impell'd by a very light Fluid; if at the first Moment of its Effort, it moves in a Line by an uniform Velocity, at the second Impulse and second Moment, it ought to move two, and at the third Moment three, &c.

Now if you take several Numbers one after another, beginning with an Unit, 1, 2, 3, 4, &c. to 20, and count 20 Moments, the Sum of this Progression will be 210; and if you count 40 Moments, according to the same Progression to 40, the Sum of these latter Numbers will be 820, which is near the Quadruple of 210, the Sum of the 20 first Numbers; but if you proceed thus, *in infinitum*, this last Sum will be the Quadruple of the first precisely, because the Proportion of the Defect continually decreases; which *Galileo* has also prov'd in his Treatise of the Acceleration of the Motion of falling Bodies.

BUT if the Motion be made through a very heavy Fluid, this Acceleration will soon be stopt, and the falling Body reduc'd to an uniform

form Velocity, as likewise a very light Body that falls in open Air, as has been prov'd in some Treatises on Percussion.

EXPERIMENT 3. *Fig. 7. Tab. seq.* Take a bended Tube two or three Foot long, of equal Breadth throughout, as C D D, pour Water in at C till it runs out at G, then stop the End G with your Finger, and pour on till you fill the Tube up to C; and after this stop the End C with another Finger, and open the End G: If the Tube be only three or four Lines in Diameter, the Water will not run out at all; take off the Finger that stoppt the End C, and put it on again very suddenly, the Water will spout out at G only four or five Lines high; whereas if the Tube C D be much wider than the Hole G; for example, if it be nine Lines in Diameter, and the End only two or three Lines, and you open and shut the small Aperture at G with the same Haste, the Drops of the Water that go out at G, will spout up almost as high as C.

You may still further perceive the Slowness of the Water's Motion at its first going out of the Tube, as A B in *Fig. 2.* and its Acceleration, if you fill this Tube with Water, and sustain it with your Finger, sustaining likewise a little Stone with another Finger on the same Hand; for taking away your Hand suddenly, you will see the Stone and the lowest part of the Water descend with the same Velocity for twelve or fifteen Foot together. Another very curious Experiment is made in the following Manner:

EXPERIMENT 4. *Fig. 8. Tab. Seq.* Take a Tube eight or ten Foot long, as M N, as smooth and even as it can be made, fill it with Water, which you must sustain with your Finger, and then of a sudden let it run out upon the End of the Rule QR, near the Point R, which Rule serving for a Ballance, ought to be horizontal, and supported at the other End by a Prop, as O V; and the Point R ought to be only five or six Lines distance from the Base of the Tube through which the Water passes, that is to say, a Line more than the Thickness of the Finger that sustains the Water; then if at the other End Q, you fix a Weight $Q \frac{1}{4}$ or $\frac{1}{5}$ less than the whole Weight of the Water in the Cylinder, this Weight will not rise at the Beginning of the Water's Fall, though the whole Body of Water seems to weigh upon R, but only when the Tube is almost empty; which shews, that only the first Parts of the Water make an Impression, and that when they go out very slowly, as they do at the Beginning of their Fall, they can only raise a Weight much less than the Weight of the whole Cylinder; but when they have acquired a great Velocity in falling from the Height M, the remaining Parts, by their great Impulse, raise what the first could not raise by their weak Impulses

pulses at the Beginning of a Fall; just as the Wheel of any Machine, which by the Impulse of the first Water that falls upon it seems to move a little, yet is not set into its uniform and regular Motion without the Accession and Impulse of the other Water that is to drive it.

To go on; If you raise the same Tube two or three Feet above R, and leave only one Inch of Water at the Bottom of it, (if the Tube be seven or eight Lines Diameter) it will have less Force in falling upon R to raise a Weight at Q, than a little Ball of Wax or Wood lighter by half than the Water falling from the same Height; which shews that the Ball makes its Impression by all its Parts, and the Inch of Water only by those that are nearest to the first Surface that impels the Ballance, and which are help'd a little by the more distant Parts that fall on each Side.

FOR though Water does not impel by all its Parts, and it be difficult to determine the precise Height of the Water from which the Part impelling ought to be estimated; yet 'tis probable that the Parts that fall first act the most, and that those that are a little higher, as two or three Lines, act a little less; and that some small Impulse may reach even five or six Lines; as it would happen if five or six Grains of Sand were contiguous to one another. *Vid. Fig. 3. Tab. seq.* As A E F D B falling upon the Rule G H, from a determinate Height, not being all in the same perpendicular Line, the two Grains D and B would still a little contribute to the Impulse of the first, though they would not act with their whole Weight, and all their Velocity not being in the same Line of Direction; the highest Grains A E F contribute likewise a little, and cause the Rule to be impell'd more strongly than if only the Grains B and D were there.

Now Water being compos'd of an infinite Number of Corpuscula or little Bodies, contiguous to one another, much less than the smallest Grains of Sand, that easily roll and slide against one another, a little Cylinder of Water, as G H, will have an Impulse something stronger than a lesser one, as L H; because there are more of these Corpuscles in a direct Station one upon another in the Height of G H, than in the lesser L H.

To proceed; the Air's Impulse may be known by an Experiment made by a Machine, (*Fig. 8. Tab. seq.*) A B C D is a cylindrical Vessel of Tin well folder'd, open at C D, and turn'd Bottom upwards into another Cylinder E F G H, in the Base of which is first a little Tube well folder'd, as L I, that goes into the inverted Cylinder, passing a little above the Water N K, that is, in the Cylinder E H, the upper Base is press'd by several Weights successively

L I

to

258 *An Introduction to a General System*

to make the Cylinder descend, and at the same time to drive out the Air with Violence through the Tube I L; to the Bottom of which a Ballance is apply'd like that describ'd *Fig. 4.* and upon one of the Ends of it different Weights are laid, to try the Force of the Air's Impulse.

HENCE it follows, that if two Cylinders full of Air, of the same Height, having unequal Bases, are press'd by equal Weights dispers'd as the Cylinder A B C D; and having equal Holes or Apertures through which the Air is to pass, the Weights which the Air rushing out will raise, will be to each other in a reciprocal Proportion of their Bases; for let either of the two Cylinders A B C D, *a b c d*, be put into another Cylinder full of Water, as was explain'd in the foregoing Figure, and let the two Weights M and *m* be placed upon these unequal Cylinders, and be equal, and the Weights rais'd be P and *p*, namely, P by M, and *p* by *m*; forasmuch as the Base G H is to the Aperture L, as the Weight M to the Weight P, rais'd by the Air going out of L, and as the Aperture E equal to L is to the Base *h g*; as the Weight *p*, rais'd by the Air going out at C, to the Weight M or *m*; the Proportion being found to be equal, the Base G H will be to the Base *h g*, as the Weight *p* to the Weight P. But if the Weights pressing upon the Cylinders be proportionable to their Bases, they will raise equal Weights by the Impulse of the Air, which they will force out at equal Apertures; as if the Base G H be 24, and the Base *g h* 12, and the Weight M be 12 Pounds, and the Weight *m* 6; the Aperture L being 4, and *l* the same, the Weight P and *p* will be each 2 Pounds, which may be very easily proved.

THERE are three Propositions or Rules more that might be taken from *Marriotte*, to demonstrate the Equilibrium and Impulse of Water in three several Cases, as by him set down, Discourse III. Rule 3. p. 125. of the Translation. The first is, that *Jet d' Eau's of equal Breadth issuing out at little Apertures, made at the Bottom of several Tubes full of Water, of different Heights, make an Equilibrium with Weights that are to each other in the Proportion of the Heights of those Tubes.*

A SECOND is, that *Jet d' Eau's of equal Breadth and unequal Velocities, sustain by their Impulse Weights that are to each other in a duplicate Proportion of those Velocities.*

A THIRD, which is indeed *Marriotte's* second, is, that *Water which spouts out at a round Hole from the Bottom of the Reservoir, makes an Equilibrium by its Impulse with a Weight equal to the Weight of a Cylinder of Water whose Base is that Hole, and*
whose

whose Height is from the Center of the Hole to the upper Center of the Water.

BUT as this will lengthen this Chapter beyond its due, and as they will in a great Measure be demonstrated by the Propositions that go before, as well as this that follows, referring my Reader, for his farther Information of them, to the Book it self; proceed we therefore to

P R O P O S I T I O N V.

Jets or Streams of the same Velocity, and different Apertures, sustain by their Impulse Weights that are to each other in a duplicate Ratio of the Diameters of those Apertures..

LET two Surfaces A B and C D have two Apertures at E and F, (Fig. 9.) and let the two Spouts or Streams E N F M, pass through these Holes, it is evident that the Surface of the Hole E is to the Surface of the Hole F, in a duplicate Proportion of the Diameter G H to the Diameter K L; and the Velocities being supposed equal, if the Diameter G H be twice as great as the Diameter K, there will be four times as many small Particles of Water to impel in the Base G H, as in the Base K L; they will then produce a quadruple Effect, and if the Surfaces of the Spouts or Streams are reciprocal to the Heights of the Reservoir or Stream from which they proceed.

FROM which it appears, that the Equilibrium, and consequently the Impulse of Air, Water, or any other Fluid, is in Proportion to its Height, and the Largeness of the Apertures, Streams or Spouts, through which, or from whence it proceeds, *and that the Spaces which Bodies go through from their Fall are in a duplicate Ratio, or as the Squares of the Times or Moments.* Which must serve as a Foundation to what we have to say on the Business of Hydraulicks or Water-Engines.

To reduce what has been said in this Chapter to Practice, omitting the Uses that might be drawn from the foregoing Propositions in Jets or Waters that spout upwards, I shall apply it chiefly to Mill-works, or the Effect it has on the Motion of Wheels in Hydraulicks or other Machines.

AND since it is evident, from the foregoing Propositions and Experiments in general, that Water that issues from any Reservoir, Mill-Pond, &c. receives *an additional Impulse and Velocity, and acts in a duplicate Ratio, or as the Squares or Times of the Spaces through which they fall,* or in other Words, according to the different Heights from whence it begins such Fall, it is or ought to be a

260 *An Introduction to a General System*

certain Direction to all Millwrights to raise the Head of Surfaces of the Water in Mill-Ponds, as high as possibly they can, even for an undershot Mill, no less than four or five Feet.

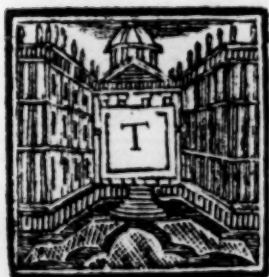
AND since it will appear also, from the following Chapter, that the Motion of Water is irregular, and that the middle Part of a Stream or River moves with more Celerity than the Bottom, because that is often obstructed by Weeds, Stones, and other Obstacles, I say, this should also instruct the industrious Millwright to fix the Trough through which the Water is to spout and lodge, on the Wheel at $\frac{2}{3}$, or rather $\frac{3}{4}$, of the Depth of the said Mill-Pond, laying it sloping in such a Manner that it may lodge the Water with greatest Advantage on the Pallats, (or which is more advisable) the Boxes of the Wheels on which you are to throw it.

AND since it is evident also, that *Jets or Spouts of Water do not* (on account of the great Number of Corpuscles of which it is compos'd) *impel with the united Force of all its parts as other Bodies do*, this ought to instruct him to confine the Water in a strong square Trough of near the Width of the Box or Pallats, cover'd over strongly at top with a Board of equal Thickness with the Trough, that so the Water may be reduc'd as near as possible to the Nature of a solid Body: For on the contrary, as may be said from daily Experience, the great Resistance of Air that is in the open Trough where the Wheel makes its Rotation, the Room there is on the Sides of the Pallats for the Water to run to waste, and to have no Effect: And the Distance there is between the Bottom of the Mill-Pond and the Pallats of the Wheel, is such, that the united Force of the Water is broken; its Strength in a great Measure lost, and as much Water again wasted as if it were confin'd, which can't be of little Estimation in Mill-Ponds and Streams where Water is scarce, especially in Summer Seasons: But of this, more in the next Chapter.



C H A P. XIV.

Of the different Impulse or Fluctuation of Water in a Mill-Pond or River (for the driving of Mill-Wheels) varied, according to the different Circumstances which attend the Fall of it.



THE Irregularities in the Motion of a River may be infinitely varied, and Rules can't be exactly given to settle them; therefore setting aside all Irregularities, we must examine the Course of Rivers, for unless the Laws of Motion be known in that Case, we have no certain Foundation for determining any, (notwithstanding it is so effectually done in Waters that fall from a precipitate determinate Heighth). To compare this Velocity of Water, then, in open Rivers by Experiments, and to determinate them as near as possible, so as to know the Spaces which it passes thro' in a certain Time, and consequently the Expence of Water, and Strength with which they strike on the Pallats of a Wheel:

LET *Fig. 10. Tab. seq.* be a Quadrant divided into Degrees, with a Thread in the Center, that has at the other End a Ball P hanging, which is heavier than Water: Let the Ball hang within the running Water, whilst you hold the Side C A of the Quadrant, in a vertical Position; the Ball, by the Motion of the Water, will be so far sustain'd, that the Thread P C will make the Angle P C A, with the Side C A, which will serve to determine the Celerity of the Water running against the Ball.

THE Ball being at Rest in the Water, is drawn by three Powers; by its Gravity it endeavours to descend vertically, by the Action of the Liquid it is carried in the Direction of the Motion of the Water; and, *Lastly*, it is drawn by the Thread along P C. Draw the Triangle E F G, in which E F represents the vertical Line: Let F G make with that Line the Angle E F G, equal to the Angle, which

which the Direction of the Motion of the River makes with the vertical Line. *Lastly*, Let the Angle $G E F$ be equal to the Angle $P C A$, the Sides of the Triangle $E F G$ are parallel to the Directions of the three Powers above-mention'd; therefore the Powers are to one another, as those Sides.

IF therefore $E F$ express the respective Gravity of the Ball, $F G$ will express the Action of the Water on the Ball; and if you make several Experiments in different Places with the same Ball, you must draw such Triangles, the Side F remaining (which denotes the respective Gravity of the Ball, that never changes) the Sides that are as $F G$ will have the same Proportions as the Actions of the Water on the Ball. But those are as the Squares of the Velocities of the Waters in the Places, in which the Experiments are made, for there is no Difference in Respect of the Action of the Water on the Ball, whether the Ball be mov'd, and the Water at Rest, or on the contrary the Water be mov'd, and the Ball at Rest.

THE Action of the Water against the Ball may be compared with the Weight it has to the respective Gravity of the Ball, as $F G$ to $E F$.

BUT this Action is equal to the Resistance which a Body suffers, when it is mov'd through quiescent Water, with the same Celerity with which the flowing Water does now strike against the Body, which is at Rest. By knowing the Weight, which is equal to the Resistance, we know what Space could be run through in a given Time, with the Celerity with which the Body moves; therefore we shall also here know what Space the Water can go through in a known Time, and so likewise what Quantity of Water flows in a given Time, through a Place given in the Section of any River or Mill-Stream.

AND here it is to be observ'd, that the Determination of the Velocity of the Water, will not be exactly settled, if the Experiment be made towards the Surface of the Water; because there the Action of the Water upon the Globe is irregular.

THIS Celerity may be determin'd, by immersing in Water a Body which is but a little lighter than Water, and which swimming at the Surface, does not float so high above it, as to be affected by the Motion of the Wind; for as the specifick Gravities of the Water, and the Body scarce differ at all, and that this Body may be look'd upon as wholly immers'd; it will move with the same Celerity as the Water, and you may, by Help of a Pendulum, measure the Time in which a Body runs through a certain Space that was measur'd

before :

before: When the Surface of the Water is agitated by the Wind, the Experiment will not succeed well, because of the Motion of the Waves, which cause an Irregularity in the Motion of the Body.

It must be considered also, (according to *Marriotte*) that the Water of a River does not go equally fast at its Surface, and its other Parts; for the Water near the Bottom is very much retarded, by meeting with Stones, Weeds, and other Inequalities.

To calculate this Difference in the Motion of Water in a River, our ingenious Author, as we have it, *Discourse III. Page 136.* put two Balls of Wax fastned to a Thread of a Foot long, into a little River, whose Motion was uniform; the one was loaded with little Stones within, to make its specifick Gravity a little heavier than that of Water; so that when the two Balls were in the Water, the heaviest stretch'd the Thread, and made the lightest sink lower than it would have done, had it been alone; and by this Means its upper Part was almost upon a Level with the Surface of the Water; so that the Wind could have no Power over it.

It was always observable, that when the lowest Ball stay'd behind, especially in the Places where there were some Weeds at the Bottom of the Water, near which the lower Ball pass'd, for this River was but about three Foot deep; but when these same Balls were put in a Place, where the Water meeting with some Obstacle rose a little, and afterwards took a more rapid Course, as is observable under Bridges, the lower Ball outwent the upper, which shews, that the Water in the Middle goes faster than that of the Surface; which proceeds from this Cause, that the Water rising a little higher, by Reason of the Obstacle it met with, acquires a greater Velocity, by running down a steeper Declivity; and this Violence causes it to plunge, and go below that of the Surface, as if A B C D be the Course of the upper Water, and by an Obstacle towards B, (*Fig. 10. Tab. seq.*) it rises to the prick'd Line E F, it will run faster along the steep Declivity E F C; and by the Velocity which it will have acquired at C, it will continue its Direction below C D as to G H, and consequently it will go swifter at G and H, than at I and D: And thence it happens, that in moderate Rivers there are always great Cavities below Bridges, caused by building of Peers of Stone, or Piles of Wood to sustain the same: Proofs of this are to be seen almost at all Places, but at none more than that of *London Bridge*, at the Flux and Reflux of the Tide, which being so well known, I need not enlarge upon it.

To explain this the better, let A B (*Fig. 11. Tab. seq.*) be an horizontal Line, and C D the Declivity of the Bottom of the River D E, the

the Water half a Foot Distance from the upper Part F G, both parallel to C B. Now, because Water is suppos'd by some to be of a viscous Nature, and its Parts a little join'd together, the Water D E will carry along with it that which is immediately above, with almost the same Velocity which it has it self, and afterwards that which is at F G, which moving likewise of it self, by Reason of its Inclination, goes a little faster than the Water D E; which may be comprehended the better, if you suppose F L to be a Board swimming upon the Water, whose upper Part is in an Inclination parallel to C B, having a very round Ball upon it, for this Board being carried along by the Water, would carry the Ball along with it, which would of it self also roll the Length of the Board to G, and consequently its Velocity would be greater than that of the Board.

IT has been further observ'd, from Weeds carried along by the Water, that those within the Water, and nearest the Bottom, being advanc'd farther than those of the Surface, were soon overtaken, and left behind by the upper ones; and if upon the same Stream a Handful of great Sawings, or heavy Wood was cast, that went some sooner to the Bottom than others; it was always found, that those that swam nearer to the Top, went before the others in a proportional Order, as they were more or less distant from the Bottom; from which Experiments it appears, that Rivers or Streams that run free by the upper Part of the Water, go faster than that in the Middle, and the Middle faster than that at the Bottom; but in those that are constrain'd to pass in a narrow Channel (being kept in on both Sides) the Middle goes swifter than the Surface, if there be but two or three Foot deeper Water. Thus far *Marriotte*. But the learned *Gravesande*, (upon the Foot of Sir *Isaac Newton's* Principles, and from his first Law of Nature, which relates to Motion (wherein he says, that all Bodies continue in their State of Rest or Motion uniformly in a right Line, except so much as they are forced to change by Forces impress'd) assigns other Methods of Motion to Water running in Streams and Rivers, supposing Water to run in a regular Channel, without any sensible Friction, and that the Channel is terminated with plain Sides, that are parallel to one another, and vertical; and also, that the Bottom is a Plane, and inclin'd to the Horizon.

LET A E be the Channel, into which the Water runs, from a greater Receptacle or Head; and let the Water always remain in the same Heighth at the Head, so that the River may be in a permanent

manent State, the Water descends along an inclined Plain, is of the same Nature, and is accelerated for the same Reason as the Motion of a Body freely falling in the open Air, and of which we have treated in the foregoing Chapter, because the same Quantity of Water flows through every Section, the Height of the Water, as you recede from the Head, is continually diminished, and the Surface of the Water will acquire the Figure *i q s*.

To determine the Velocity of Water in different Places, let us suppose the Hollow of the Channel *A D C B* to be shut up with a Plane; if there be a Hole made in the Plane, the Water will spout the faster through the Hole, as the Hole is more distant from the Surface of the Water *h i*, and the Water will have the same Celerity that a Body falling from the Surface of the Water to the Depth of the Hole below it would acquire, which arises from the Pressure of the superincumbent Air, Water, &c. as has been said in the foregoing Chapter.

THERE is in like Manner the same Pressure, that is, the same moving Force; when the Obstacle at *A C* is taken away, then every Particle of the Water enters into the Channel, with the Celerity that a Body would acquire, in falling from the Surface of the Water, to the Depth of that Particle, and this Particle is mov'd along the inclin'd Plane in the Channel, with an accelerated Motion, and in the same Manner, as if vertically falling it had continued its Motion to the same Depth below the Surface of the Water in the Head of the River: So that if you draw the horizontal Line *i t*, the Particle at *r* will have the same Celerity as a Body falling the Length *i C*, and running down *C r* can acquire, which is the Celerity acquired by the Body in falling down *t r*.

ON which Account it is, that the Celerity of a Particle may be every where measur'd, drawing from it a Perpendicular to the Horizontal Plane, which is conceived to run along the Water in the Head of the River, and the Velocity which a Body in the Fall from that Perpendicular will be, the Celerity of the Particle (which by the Rules laid down in the last Chapter) will be the greater, the higher or the longer the Perpendicular is.

FROM any Point, as *r* draw *r s* perpendicular to the Bottom of the River, which will measure the Height or Depth of the River, since *r s* is inclin'd to the Horizon; if from the several Points of that Line you draw perpendicular to it *i t*, they will be the shorter, the more distant they are from *r*, and the shortest of them all will be *f v*: Therefore the Celerity of the Particles in the Line *r s* are so much the less, the nearer they are to the Surface of the

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River,

266 *An Introduction to a General System*

River, and the lower Water is, in such a Case, mov'd faster than the upper Water; but yet the Celerities of those Waters, as the River runs on, continually approach nearer and nearer to an Equality; for the Squares of those Celerities are as rt to sv , the Difference of which Lines, as you recede from the Head of the River, is continually lessen'd, because of the Line rs , which is continually diminish'd, as the Lines themselves are lengthned. Now, as this obtains in the Squares, it will much more obtain in the Celerities themselves, whose Difference therefore is diminish'd as they increase.

If the Inclination of the Bottom be chang'd at the Head of the River, so as to become yz , and a greater Quantity of Water flows in the Channel, it will be higher every where in the River, but the Celerity of the Water is no where changed; for this Celerity does not depend upon the Heighth of the Water in the River, but (as has been demonstrated) from the Distance of the moved Particle, from the Horizontal Plane of the Surface at the Head, continued over the said Particle, which Distance is measur'd by the Perpendicular rt or sv : But these Lines are not chang'd by the Affluence of the Water, provided that the Water remains at the same Heighth in the Bason or Head.

LET the upper Part of the Channel be stop'd up by any Obstacle, as X , which descends a little Way below the Surface of the Water, the whole Water which comes cannot run through, therefore it must rise up; but the Celerity of the Water below the Cataract is not encreas'd, and the Water that comes on is continually heap'd up; so that at last it must rise so, as to flow over the Obstacle, or the Banks of the River: But if the Banks be rais'd, and the Obstacle continued, the Heighth of the Water would rise above the Line it , but before that the Celerity of the Water cannot be increas'd; in which Case the Heighth of all the Water in the Head will be increas'd; for as we suppose the River in a permanent State, there must continually be as great a Supply of Water to the Head, as there runs from it down the Channel; but if less Water runs down, the Heighth must necessarily be increased in the Head, till the Celerity of the Water flowing under the Obstacle be so much encreased, as that the same Quantity of Water shall run under the Obstacle, which used to run in the open Channel before.

ALL these Things (as has been already said) if we abstract from the Irregularities, are true, and the less the Irregularities are, the more will the true Motions agree with what has been said, concerning which, before any Judgment can be made, the Velocities

cities of Water by other Experiments must be compar'd, that these Velocities themselves may be so determin'd, as to know the Spaces gone through in a certain Time, which is what has already been attempted, and will be more demonstrable by what follows in this Chapter.

(WITH *Marriotte* then, Discourse III. Rule 5. Page 133. of his *Hydrostaticks*) to estimate the Force and Current of Water, against the Paddles, Pallats or Floats of a Mill, or any other Machine, you must know its Celerity or Velocity, and compare it with that of Water spouting from the Bottom of a Reservatory. It is likewise necessary to know the specifick Gravity of Water, with Respect to other Bodies, concerning which the following Observations have been made by that industrious Author.

A cubick Vessel was prepared, made of Copper, one of whose Sides was six Inches, and consequently its Content the eighth Part of a cubick Foot, which put into one of the Scales of a Balance, and a Weight equal to it in the other; afterwards it was fill'd very carefully with Water, through a little Hole, made towards an Angle in the upper Plate: And it was found, by several Trials, that this Water weighed 8 $l. \frac{3}{4}$. and consequently that a cubick Foot of Water ought to weigh 70 Pounds, the *Paris* Muid or Barrel contains 8 cubick Feet, and every cubick Foot 36 Pints *French*, about so many Quarts *English*, when the Measure is so exact, as that the Water does not rise above the Brims; but when it rises as much above the Brims as it may, without running over; it contains only 35 Pints *French*, 35 Quarts *English*; and every one of these last Pints weighs 2 Pounds, and the other 2 Pounds wanting 7 Drams: The *Paris* Muid or Barrel contains 288 of these latter Pints, and 280 of the other: From thence it is known, that a Cylinder of Water a Foot in Height, and whose Base is a Foot in Diameter, weighs 55 $l.$ (or with *Ozanan*, *Cap. II. Book III.* of his *Mechanicks* 54) Pounds, because the Proportion of a Circle to the Square that circumscribes it, is as 11 to 14: Now, as 14 is to 11, so are 70 Pounds to 55; whence you know, that a Cylinder a Foot high, and an Inch in Base, weighs 6 Ounces and a Dram very near (and according to *Ozanan* before mention'd, a cubick Inch weighs 3 Drams 3 Grains) for the 144 Part of 55 Pounds is 6 Ounces $1 \frac{1}{2}$: Whereupon the following Experiments were made.

HAVING fastned a little Boat, to another very great one, that was immovable in the Midst of the Stream of a River, where it was very rapid, a Distance of 15 Foot was measur'd lengthwise

on the little Boat; afterwards a little Piece of Wood was thrown out, or a Blade of Grass 2 or 3 Foot from this little Boat, over-against the Place where the first Mark of the 15 Foot was; and by the Vibrations of a half second Pendulum, was counted how many half Seconds it was in passing from one Mark to the other; if it pass'd in 10 half Seconds, it was concluded, that in that Place the River went with a Velocity of 3 Foot in the Second.

AFTER that there was Use made of an Axis, with two Rulers a-cross them, in such a Manner, that the Planes, in which they were, cut each other, at right Angles: At the End of these Rulers was fix'd a little thin square Board, 6 Inches broad, that dipp'd perpendicularly into the Stream, till the Water rose 2 or 3 Inches above it; and at the same Time, at the End of the other Rule, that was in a Horizontal Position, a Weight was put, at the same Distance from the Axis as the Middle of the Board, and increas'd or diminish'd it, till it made an *Equilibrium* with the Impulse of the Water against the Pallet or little Board.

SEVERAL of these Experiments were made in that Part of the River, where the Stream was most rapid, and in other Places, where the Water did not go so fast; and there was always found, pretty near the same Proportions, correspondent to the Force of Water issuing to the Bottom of a Tube 12 Foot high; to make the Calculation of which, this is the Method.

IT having been found, as before, that the most rapid Water went 3 Foot $\frac{1}{4}$ in a Second, and that there it sustain'd by its Impulse against the Pallet, 3 Pounds $\frac{1}{4}$, it was concluded, that the Jet, from the Bottom of a Reservatory, 12 Foot in Heighth, goes out with a Velocity of 24 Foot in a Second, according to the Doctrine of *Gallileo*, before explain'd. This Velocity then is about 7 Times $\frac{1}{2}$ greater than that of the River, the Square $7\frac{1}{2}$ is $56\frac{1}{4}$; and consequently if this Jet be of the same Breadth as the Pallet, it ought to sustain a Weight about 56 Times greater. Now, 12 Cubick Feet of Water weighs 840 Pounds, the Quarter of which is 210 Pounds, which we take, because the Pallet which is but half a Foot square, and 12 Foot high, weighs 210; and if you divide 210 by 56, the Quotient will be 3 Pounds $\frac{1}{4}$, the Weight found by the Experiment.

Now, the Calculation of the Impulse or Force of Wind against the Sails of a Windmill, may be made after the following Manner: It being premis'd before, that though Water be of a much denser heavier Nature than Air, even as 24 to 1, yet to make Amends, its Velocity is also so much greater than Water, so that
what

what it wants of Weight it has in Celerity or Impulse, and that ejected Air, producing the same Effect by its Impulse, as a *Jet d'Eau* of equal Breadth, must have a Velocity about 24 Times greater than that of Water: Let the following be the Experiment.

TAKE a Cylinderick Machine, with Rulers like that before described, (*Fig. 5. Tab. seq.*) Let A B represent its Axis, G H, is an Horizontal Ruler, that goes through the Axis of the Cylinder at right Angles: I L is another Ruler plac'd perpendicularly upon G H; again M N O P is a perpendicular Ruler, plac'd obliquely in an Angle of 45 Degrees, in Respect of the Ruler G R. Now, if you suppose a Jet of Water to strike directly upon the Ruler I L, at the Point Q, so as to turn the Cylinder, according to the Order of the Letters *a b c d*, it will act with all its Force to sustain the Weight R; but if another Jet equal to it strike the Ruler *m o* directly at the Point S, which you suppose as far distant from the Axis as the Point Q, it cannot sustain the Weight R, because its Direction will not be parallel to the Direction of the Extremity of the Ruler I L; and it can only sustain a Weight, that will be to the Weight R, as the Side of a Square to its Diagonal; and if the same Jet be parallel to the Axis A B, and strikes at the same Point S, you must still diminish the Weight R in the same Proportion, to make the *Equilibrium*, because this Jet will strike this Ruler obliquely in an Angle of 45 Degrees, and then R will have but half its Weight; for if A B C D, *Fig. 6. Tab. seq.* be a Square, the *Ratio* will be as that of A C to A B, and the second as that of A B to A E, the Half of A C.

Now, the Wind that drives the Sails of a Wind-mill, strikes against them obliquely; and if it meet every Sail in an Angle of 45 Degrees, no more of its Force would remain than in the Proportion of a Diagonal of a Square to its Side, for that Reason only; but if that Sail, which is oblique to the Axis, were so in the same Angle, this second Cause would still diminish the Force of the Wind in the same Proportion, as was said before of the *Jet d'Eau*; and the total Diminution from these two Causes would be of half the Force of this Wind, when it strikes against this Ruler, as I L, dispos'd more at the Beginning, according to its Direction: So that, if its Total Force was so, it would be reduced to forty by these two Causes.

BUT Because the Sail, whose Obliquity is 45 Dgrees, receives a less Breadth of the Wind, than when it is directly oppos'd to it, it still receives a third Diminution in the same Ratio, as A C to A B, and the Total Diminution will be as A C to E F, or merely
as

270 *An Introduction to a General System*

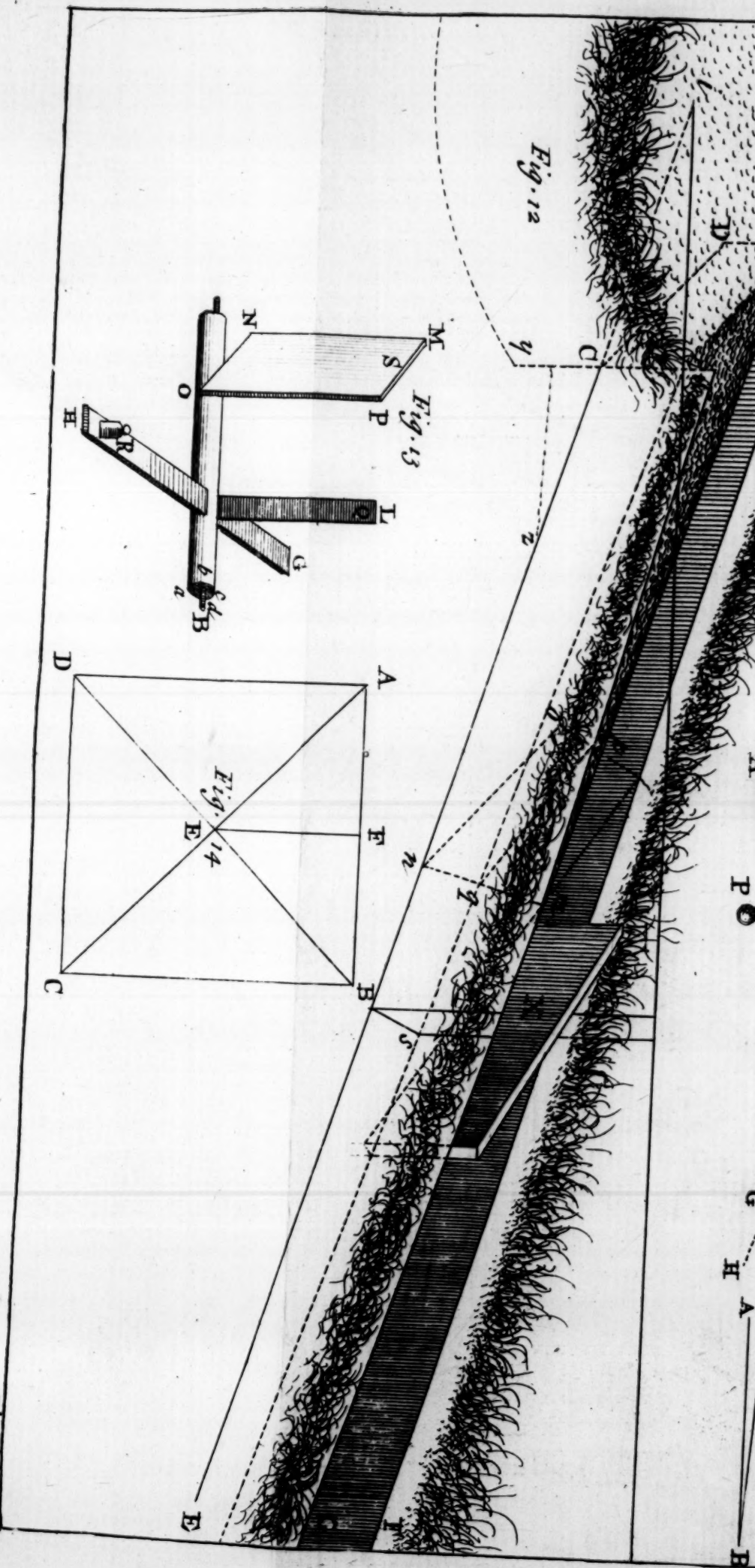
as 80 to $28 \frac{1}{4}$. But if the Obliquity of the Sail be N O, and the Angle made by A B and N O be of 60 Degrees, *Fig. 5. Tab. seq.* then the first Cause alone will diminish half the Force of the Wind, and reduce it from 80 to 40, and the two others together will reduce it from 40 to 31, or very near: Whence may be judg'd, that it is better that the Sails of a Wind-mill should have the Obliquity of 60 Degrees, rather than that of 45, which they are generally made.

To illustrate this Matter yet further, and to calculate the Force of Wind that blows directly against the Sails of a Ship, the Velocity of the Wind must be found out, and which may be done by the letting down of a very light Feather, to be carried by the Wind from some fix'd Place, and observing the Time that it takes up in running through a certain Space, as 30 or 40 Foot.

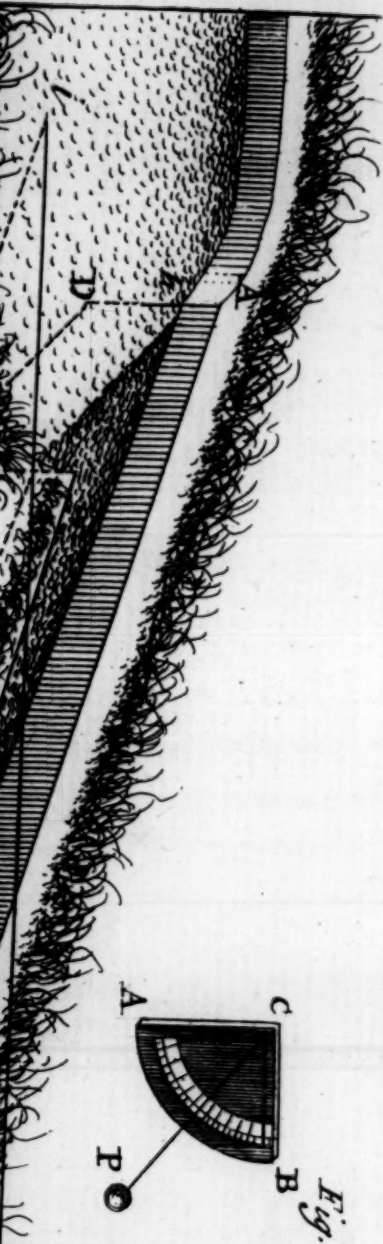
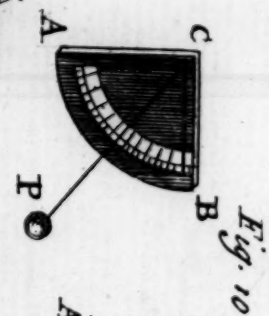
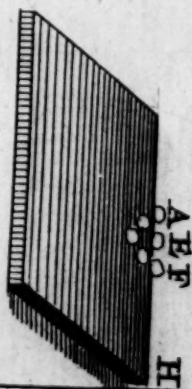
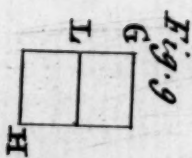
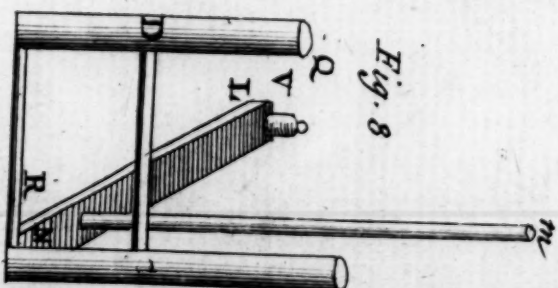
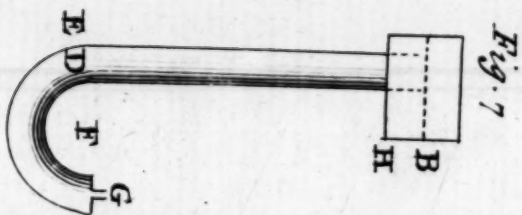
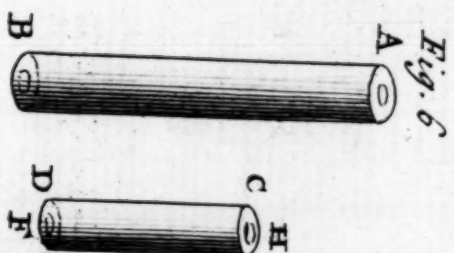
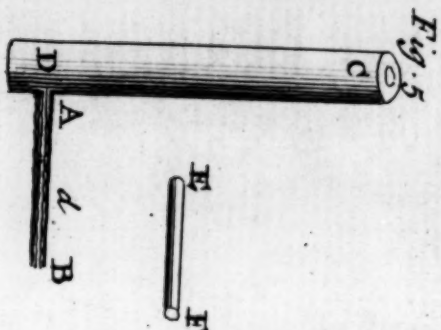
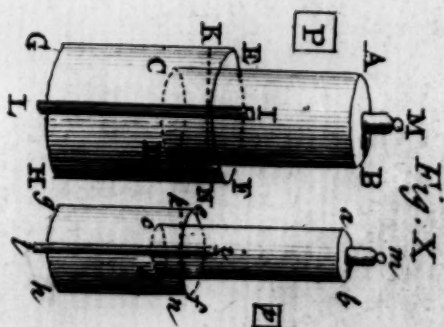
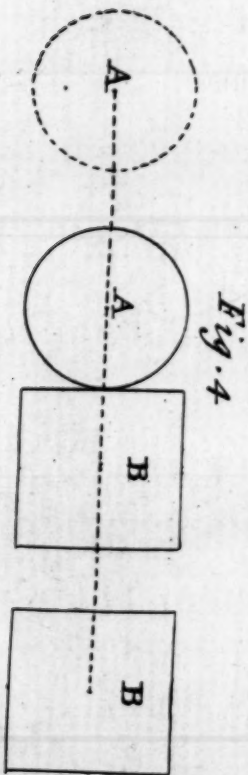
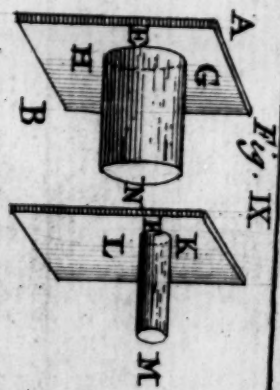
N o w, supposing Wind to go 24 Foot in a Second, it will go as fast as a Jet that spouts from a Hole of 12 Foot below the Surface of its Reservoir or Pond (as has been before observ'd) and because the Wind ought to go 24 Times faster than the Water, to produce the same Effect, it will perform no more than Water of an equal Breadth, that goes but one Foot in a Second, or than the Jet that goes 24, if the Breadth of the Wind be 24 Times greater in Diameter, or 576 Foot in Surface.

N o w, a Jet half a Foot square, coming from a Reservoir or Mill-pond, can sustain, (as was said before) a Weight equal to the Weight of a square Column of Water, whose Base is half a Foot square, and whose Height is 12 Foot; and since a 6 Inch Cube (by the foregoing Tables) weighs $8 \frac{1}{4}$, if you double this Height, it will be 17 Pounds $\frac{1}{2}$ for a square Column of Water, of a Foot long, and half a Foot broad; and if it be 11 Foot long, 210 Pounds will be sustain'd by a Jet half a Foot square.

T H A T the Wind then, moving with this Velocity, may sustain the Weight of 210 Pounds, the Sail that impels it must be 24 broader and longer than half a Foot, that is to say, it must be 12 Foot broad, as well as long, or 6 Foot broad, and 24 Foot long, and then the Wind that goes 24 Foot in a second, will sustain 210 Pounds plac'd upon an horizontal Ruler, fastned to the same Axis as the square Sail of 12 Foot, at the same Distance from the Axis as the Middle of the Length of the Sail, which ought to be in a perpendicular Situation; but if the Wind goes but 12 Foot (which may be tried by the foremention'd Experiment) it will support but 52 Pounds and a Half, which is one Quarter of 210 Pounds.



Tom's Sculpt



IF you would know the Experiment in Miniature, you must make use of the Axis describ'd, (*Fig. 5. Tab. seq.*) and take a Sail a Foot Broad, and a Foot long, whose Surface being a Foot will support but 144th Part of 52 $\frac{1}{2}$, namely 5 Ounces $\frac{1}{2}$, if this Weight be of the same Distance from the Axis, in the Middle of this little Sail; but you must chuse a Wind that goes 12 Foot in a second.

FROM the following Method, says our oft-quoted *Marriotte*, may be easily calculated the different Forces of Water and Wind, by their Impulse.

SUPPOSE that each of the Sails is 30 Foot long, and 6 Foot broad, which produces 180 Foot; if the Wind goes but 12 Foot in a second, it sustains 5 Ounces $\frac{2}{3}$; when it impels a Sail of a Foot Surface; but if it impels 180 Foot in Surface, it will sustain almost 66 Pounds, but you must take away $\frac{1}{3}$, by Reason of the triple Obliquity of the Impulse (as was before prov'd): If the Obliquity be of 30 Degrees, there will remain 29 Pounds, and the four Sails will sustain 100 Pounds; but the Distance of the Axis from the Middle of the Wheel, and that from the Middle of the Floats, to their Axis, is but 4 Foot.

THEN, by this Cause, the Wind-mills will augment their Force in a Quintuple Proportion; and if the Cogg-wheel be two Foot in Diameter, the Force of the Wind-mill will be ten Times 100, and that of the Water-mills twice 466 Pounds, when the Wind goes 12 Foot in a second, and the Stream of the Water 4 Foot, you may make the like Calculations for greater or lesser Sails.

THE naked Fan or Skeleton of the Sails of a Wind-mill are generally made 1 Foot from the Center of the Axis: It is 2 Foot from the said Axis, or Center of the Axle-tree, to the Beginning of the Fan, and the Width of the Top of the naked Fann is 32 Foot, and 4 $\frac{1}{2}$ Foot long; so that the general Dimension or Square of the Sail is 32 Foot.

THE laborious *Ozanan*, in his Treatise of simple and compound Engines, *Cap. VII. Page 53.* thus describes an Engine, wherein the Wind is made Use of for a moving Power, (*viz.*) in a Wind-mill, where the Wind blowing round the Sails A B (when their Canvas is stretch'd (which in such a Case are Leavers) causes the Axle C D to turn horizontally, and the Wheel E F vertically, whose Coggs take the Rounds of the Trundle.



C H A P. XV.

Of Mill-wheels for raising Water, &c. their Dimensions, Strength, Position and the like; and also of the best Places for setting of Mills.



H A T has hitherto been set down, has chiefly had Relation to the Proportion, which the Perimeter of the Axis of a Wheel has to the Perimeter of the extreme Orb, to which any Force is join'd, or that the Semidiameter of the one has to the Semidiameter of the other, for their better Force in moving of great Weights; as also of the Power of multiplying Wheels, to that End and Purpose. But before I quit this Doctrine, of the Rowls or Wheels, in the Axis in *Peritrochio*, it may not be improper to subjoin some Speculations concerning these rotund Instruments, and moving Bodies, that our Calculations under this Head may be the more intelligible, and better understood.

I T is a common Observation, and that which *Aristotle*, in Question the 9th of his *Mechanicks* touches upon, *That large Wheels, Cylinders, and Spheres move with more Ease than small ones.* But as this is not always true, and as there will be Occasion to limit this extensive Doctrine, and to bring it into the best Light we can, let us reduce the Matter to its first Principle; and suppose that a Cylinder, such as *Aristotle* calls the *Scytalis*, or Roller, that is us'd in Gardens, or for the smoothing of any other Piece of Ground, such as is exhibited in *Fig. 6. Tab. seq.* If the Weight and Length of the Cylinder be equal, tho' the Diameter be more in the one than the other, it is plain, from every Day's Experience, that you may roll the larger with more Ease, than you do the lesser, because in the first Place, the Center of the large Cylinder is higher from the Plan of the Earth, than the Center or Axis of the lower, and consequently a Man or a Horse pulls at it with the greater Force, the whole Strain being Horizontal; but this I say is when the two Cylinders are made of different

rent Materials, the one of Wood, and the other of Stone or Lead, of equal Length and equal Weight, though of different Diameters; and this is agreeable to that of the learned *Wallis*, *Cap. 7. Prop. 1.* of his *Mechanicks*, *Fig. 258.* where (treating of the Axis in *Peritrochio*) it is evident, that the Force of the Pully is nearly horizontal, at most not above 5 Degrees from it; for if the Rope at *P* were fastened, in order to be wound up more towards *B*, the higher you go, the more Difficulty you would meet with, in drawing the Burden *n R s* on.

BUT, notwithstanding this happens in small Bodies, as Rollers, and other smaller Cylinders, and lower Wheels; yet if we consider the Resistance of Air, it is manifest, that the greater Circumference a Wheel is of, so much the larger Portion of Air it has to contend with, and consequently the greater is the Friction or Resistance, and that large Wheels move with more Difficulty than small ones; and this seems to me to be one Reason why they have chang'd many of their large undershot Wheels, in their cloathing Mills about *Braintree* in *Essex*, and other Places, for those that are smaller; since though the Weight of Water is to Air, as 800 is to 1, yet where there is but little Water, and the Wheel of such a vast Magnitude, 800 Weight added to the other Weight or Offices the Wheel is to perform, is a great Incumbrance: However, where there is Water enough, and to spare, and where the Ascent is very high, that you force your Water, and consequently the Weight great (certain enough it is) that the larger your Wheel is, the greater Weight it will raise, and the higher it will throw your Water; and where the Strength of the Stream is capable of overballancing the Resistance, and exterior Pressure of Air, the Use of the Mills before spoke of, not requiring so great Strength as those do, that are employ'd in raising great Quantities of Water, 'tis there the latter are to be chose, and prefer'd.

BUT again, in Relation to Wheels, and their different Sizes and Positions, it is very certain, that overshot ones are best, where you have but little Water, as being drove by a much less Quantity thereof, than undershot Wheels are; for, as has been observ'd before, in the Crane or Tread-wheel, where a Man is endeavouring to climb up, if the Man's Weight were at (*A*), instead of (*a*), and touch'd the Orbit of the Tangent Line directly, rather than obliquely, the Wheel would move with the more Velocity, and consequently elevate the more Weight; how much more when the Water falls into the Top of the Wheel at *C*, where, by undoubted Experiments,

periments, it has six times the Force, and will consequently raise six times the Weight, than when it falls in at (a); and as a farther Consequence, still a sixth Part of the Water will serve for the driving an overshot Wheel, that does an undershot; and the true Reason why there are not more overshot Wheels, is that in most Places, especially in flattish Meadows, the Mill-Pond or Head of Water cannot be well rais'd above 4 or 5 Foot high at most; and in those Places likewise there are very great Quantities of Water, sufficient for the strongest undershot Wheel, whilst in the mean Time, no overshot Wheel can be reckoned of any Account under 7 or 8 Foot Diameter, if they be 10, 15, 20 the better: In the Mines of *Durham*, at *Lumley Castle*, I have seen an Overshot of 28 Feet Diameter.

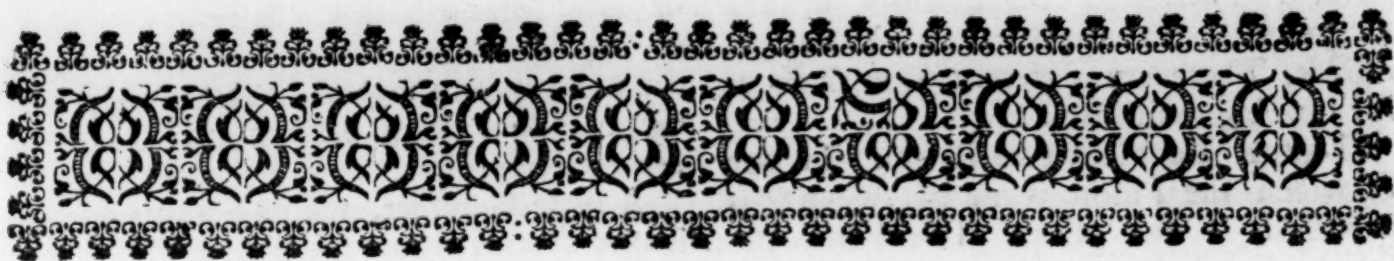
AND this leads me to what I have been all along aiming at; I mean the Position of Mills, the Diameter of their Wheels, and the like.

NOW, as to the Position of Mills, it is certain they should be as near the Place (to which you throw your Water) as possible; but the main Consideration is, how you shall place it so, as that you may have a good Mill-pool or Head, and also an easy Passage for your Mill-Tail, or Back-water; so that generally speaking, a Mill should be plac'd upon a midling Hill, near a Hollow, that the wast Water may pass off the quicker, so as to save Labour and Expence; or if the Ground be a little lowish, as it is in all low Meadow-land, you must bank up the Sides to what Height you can: But thus far Nature and common Experience directs, that you should forsake the low Ground, and keep as close as you can to the Sides of that which lies higher.

IT is as well known also, that the farther you go back, the higher may you make your Bank, and Mill-pond, which should be took, where the Owner can, half a Mile, a Mile, or two or three.

BUT as every Mill-wright, or his Master, can not have such a Command, but must be content with what the Rise of his own Land will allow, in (perhaps) 2, 3, 4, or 500 Yards (for he must not penn up the Water, to the Damage of other People, that lye behind him): By the Rules before laid down, he must take the Descent; and if he finds he can make his Cutt, or Mill-pool 7 or 8 Foot high, why then he may venture at an overshot Wheel, if he has but little Water; but if he has a great deal, he need not strain so hard, as to attempt at so great a Height, but be content with 4, 5, or 6 Foot Diameter (seldom more, as he pleases) and now the Position of the Mills, the Diameter of the Wheels, and the like being settled, thus proceed to the Work and Frame of the Wheel, &c. it self.





NOTES on BOOK II. CHAP. IO.

Of the Air-Pump. Fig. 8. Plate 9.

IT having been my Method in two or three Chapters going before, to add some few Notes, for the better Illustration of the Chapters foregoing; I take the same Liberty in this, in order to the fuller Explanation of the wonderful Properties of Elastick Air, as it is discovered by the Air-Pump, tho' something is in the Text already hinted: And first of all, I shall give a Description of the Air-Pump, as it is contriv'd by *Gravesande* in his *Mathematical Elements of Natural Philosophy*: And this I do, for a further Demonstration of the Elastick Power of Air, which is largely treated of in some of the Chapters going before; because the Elasticity of Air is explained in the Construction and Uses of a Machine, by which the Air may be drawn out of any Vessel; and this Machine is call'd an Air-Pump, and is made several Ways: The chief Part in all of them is a Barrel, or hollow Cylinder of Metal, bored smooth, and polished in the Inside; in this Barrel must move a Piston, that fills its Bore so exactly as to let no Air slip by. This Piston is thrust down close to the Bottom of the Barrel, and then raised up in such Manner, as to exclude all the Air from the Cavity of the Cylinder or Barrel; if

this Cavity communicates with any Vessel by means of a Pipe at the Bottom of the Barrel, the Air in the Vessel will expand itself, and part of it will enter into the Barrel, so that the Air in the Barrel, and in the Vessel will have the same Density. At the shutting up of the Communication between the Vessel and Barrel, and letting the Air out of the Barrel, apply the Piston close to the Bottom. If you raise the Piston a second Time, and open the Communication between the Barrel and Vessel above-mentioned, the Density of the Air in the Vessel will again be diminished; and repeating the Motion of the Piston, the Air in the Vessel will be reduced to the least Density. Yet all the Air can never be exhausted by this Method; for at every Stroke the Air does so expand it self, as to have the same Density in the Barrel as in the Vessel, in which last therefore there is always a little Air left.

ALL Air-Pumps have in common the Parts above described, but they differ in several other Things. *First*, The Communication between the Receiver to be exhausted, and the Cylinder or Barrel, is opened and shut different Ways. *Secondly*, There are different Ways of getting the Air out of the Cylinder or Barrel, when

the Piston is brought to the Bottom. *Thirdly*, The Pistons differ in different Pumps. *Fourthly*, The Position of the Cylinder is not the same in all Pumps. *Fifthly*, There are different Contrivances for moving the Piston.

THERE are often two Barrels; in one of which the Piston is raised, when it is depress'd in the other. The Pump describ'd *Fig. 8. Plate 9.* has two Brass Barrels C, C, of 2 Inches Diameter, and about 5 Inches high.

IN these Barrels the Pistons move, one of which descends, while the other rises, which Motion is communicated to them by the Wheel at Top, which is moved by the Handle M M, *Fig. 9. Plate 9.* fix'd to the Axis a. The angular Motion of the Wheel, is the eighth Part of a Circle, by which in a less Wheel there is produc'd an angular Motion of 120 Degrees. This lesser Wheel is fixed to a third Wheel, by Means of which the Pistons are immediately moved; they make a Stroke of 3 Inches and a half.

THE Contrivance of the Piston is much the same as in the Pumps which they use in *England*; tho' we think that we have made ours more perfect, by some Alterations in them.

THE Glass is to be exhausted, or set upon the round Plate L L; they communicate with the Barrels, by Means of a Pipe, one End of which is at D, and which solder'd to the lower Side of the Plate, the Continuation of this Tube is seen at E E; there are two Cocks in it, E E, between the Cocks is fixed the Pipe l, l, which communicates with the Cylinders C, C.

WHEN the Air is exhausted, one of the Cocks above-mention'd serves to shut the Communication between the Receiver (so the Glasses are call'd from which the Air is to be pumped out) and the Barrels; the other Cock serves to let the Air in again, and to cut off the Communication with the Mercurial Gage.

THIS Mercurial Gage could not be conveniently represented in this Figure; it serves to determine what Quantity of Air

is drawn out of the Receiver, as also what Quantity of Air remains in it; it is likewise of Use for measuring the solid Contents of the Receivers, which ought to be exactly known in several Experiments; our Gage differs from the common Gages in several Respects.

A little Cylinder, with a Screw upon it, is often screwed into the Plate at D, for applying a Globe to be exhausted to the Pump.

IN the Middle of the Plate L L, there is a Hole, which is shut up with a Screw; but sometimes it serves for joining several Machines to the Plate.

By this Means also, there is often applied to the Pump a cylindrick Box, full of Leathers soak'd in Wax, thro' the Center of which a Brass Wire passes, which may be moved by the Help of a Handle, so as to communicate Motion into a Place void of Air; the Box has a Cover, which enters into it with a Screw, for pressing the Leathers together, and to prevent the entering in, or escaping out of the Air; such a Box or Collar of Leathers, is often joined to the Cover which is laid over the Recipients, as may be seen in *Fig. 10. Plate 9.*

WHEN the Receivers are laid upon the Plate L, L, or when the Receivers are sloped with Covers, or when the Screws are joined to the Machine, and in general, when the Air is to be hinder'd from running in, we make use of Wax, which is soften'd by mixing as much Oil and Water to it as is found necessary.

The Last Account of an Air-Pump, which I shall produce, is that contriv'd by the late Ingenious Mr. Hawksbee, and which he made use of in all his Physico-Mechanical Experiments, being esteemed the best in its Kind that is extant.

THIS Pump, which is delineated *Fig. 11. Plate 9.* consists of two Brass Barrels or Cylinders, as represented by a a a a, twelve Inches in height, and two their Diameters within. The Suckers, or *Emboli*, are raised and depress'd by turning the

the Handle at the Center *f* backward and forward. The Winch is fasten'd to a Spindle, that passes through a Lanthorn, whose Pins perform the Office of Cogs: For in its Motion they lay hold on the Teeth of the Racks *c c c c*, and so, reciprocally, as one is depress'd, the other is elevated: By which Means the Valves, which are made of limber Bladder, and fix'd on the upper Part of each *Embolus*, as well as at the Bottom of the foremention'd Cylinders, perform their Offices mutually of exhausting and discharging the same Air taken from the Recipient on the Plate of the Pump. And when the Recipient comes to be pretty well exhausted of its contain'd Air, the Pressure of the outward Air on the descending Sucker is nearly so great, that the Power requir'd to raise the other is very little more than what surmounts the Friction of the moving Parts; which renders this Pump preferable to all others: For in the working of them, the nearer they approach to a *Vacuum*, the greater is their Labour. But this that I am now describing (under the same Circumstances) is quite contrary.

THE Bottom of the Barrels are placed in a Brass Dish, represented by *d d*, whose Sides are about two Inches high, and is on purpose to put Water in, to keep the Leather Collars (on which the Brass Cylinders stand) moist, whereby the Air is prevented from insinuating into the Cylinders of those Parts.

The Cylinders are screw'd down on the same by the Nuts *e e e e*, which force the Frontispiece *f f* down on them, thro' which the two Pillars *g g g g* pass.

THE Pillars have an Iron belonging to each of them, and pass from them in the Form of a Swan's Neck, decypher'd by *g g*, which Irons are fasten'd to the hinder Part of the Frame, for their better Security from shaking.

FROM between the two Brass Barrels arises a Brass hollow Wire, *h h h h*, which hath a Communication with each of them, by means of a perforated Piece of Brass which lies along horizontally from one to the other.

THE upper End of this hollow Wire is fasten'd to another Piece of perforated Brass, which screws on underneath the Plate *iii i*, which is ten Inches over, and has a Brass Rim solder'd on it, to prevent the shedding of Water; for which there is Occasion in several Experiments. Between the Middle and the Side of this Plate arises a small Pipe *k*, about an Inch and an half in height, through which, into the foremention'd hollow Wire, passes all the Air into the Barrels, as it is taken from the exhausting Receiver. Upon the Plate of the Pump is always laid a wet Leather, on which the Recipients are placed: This wet Leather prevents the Air getting into the Glasses, whose Edges are truly ground, and is of use for that Purpose beyond any Cement whatsoever; and not only secures it from the Air's Ingress that Way, but by the Use of it we can make several Experiments in the same Time they could formerly make one, without any Daubing or Difficulty.

Another Excellency in this Pump is, the Contrivance of the Gage denoted by *l l l l*; which Gage is a Glass Tube about 34 Inches long, and is so placed, that it cannot easily receive Damage, and is altogether out of the Way of any thing that is experimented on the Pump. Its lower Orifice is plung'd in a Glass of Mercury describ'd by *m m*, on the Surface of which is laid a piece of Cork with a Hole in the middle of the Glass Tube to pass thro': On this Cork is plac'd a Board made of Box-Wood, about an Inch in Breadth, and groov'd in the middle to receive the foremention'd Glass Tube, which is loosely loop'd on to the same by two Brass Loops, that it may have the Liberty of rising and falling, as the Mercury ascends or descends in the Gage.

To the upper part of this Tube is cemented a Brass Head, which Brass Head fits into the forementioned perforated Brass Piece that is screw'd on under the Plate, and has a Communication as well with the Recipient on the same, as with the hollow Brass Wire *h h h h* passing between the two Barrels.

THE Box Board is graduated into Inches and Quarters, from the Surface of the Quicksilver to 28 Inches high: From thence 'tis divided into Tenths of Inches. From this Gage the Degrees of Rarefaction in any Experiment are at all times most nicely to be observed.

THE Air-Cock *n*, which lets in the Air, is likewise a Screw on the same foremen-

tion'd perforated Brass, in which the upper parts of the Gage and hollow Wire are inserted: *oooo* represents a Receiver standing on the Plate of the Pump, on whose upper part *pp*, through a Box of Collars of Leather, passes a Slip Wire, whose Office is to take up, let fall, or suspend any Thing at any determinate Height, in the Receiver, without the Air's Insinuation.



Book II. Page 194.

The Pressure of Air depends upon its Height.

THAT I might finish what I have to add, as to the Weight and Gravitation of Air, I have added this Note out of *Marriotte*, which is, I humbly conceive, amongst the most curious of all his Experiments.

THE Weight of Air (says he) is still farther prov'd by an Experiment curious enough: Take a Glass Bottle *AB* (*Fig. 4. Tab. 6.*) in which there is an Hole made of 2 or 3 Lines, as at *C*; put a Glass Tube as *DE* about two Lines Diameter into the Neck of the Bottle, as at *G*, and cement them together with a Mixture of Wax and Turpentine, or with Pitch, so that the Air can't get between them; then laying the Bottle along, through the Aperture *C*, you fill it with Water, and fill likewise at the same time the Tube *ED*, keeping the End *D* close stopp'd; and when you place the Bottle in its perpendicular Situation, the Water in the Tube will descend to *E*, and as much will go out through the Hole *C*, if the Extremity *E* of the Tube answers in Height to the Middle of the Hole *C*; but if the Tube reaches down below the Hole

as far as *I*, the Water will cease running, when the Tube is empty as far as *E*, and the Bottle will remain full of Water up to the cemented Neck towards *G*; but if the End of the Tube be a little higher than the Top of the Hole *C*, as at *L*, and it be two or three Lines broad, then you will see the Air go out through this open End, and rise again to the Top of the Bottle, and at the same time the Water will go out through the Hole *C*, till there be none left above the Point *C*.

These Effects are explained in the following Manner.

The External Air pressing towards the Hole *C* by its Weight, endeavours to push up the Water, which endeavours by its Weight to get out, and the Air which is above the Tube *ED* presses likewise, and acts by its Gravity upon the Water contain'd in the Tube, which being join'd to the Weight of that Water, must overpoise the Weight of the Air which acts at *C*, which causes the Water in that Tube to descend

descend to E, and then the Air pressing on one Side at E, and on the other at C, jointly sustain the Water in the Bottle from E and C, up to A and H, and it wou'd even sustain it, though the Height CH were of 30 Feet, provided the End of the Tube were below the Bottom of the Hole C; but when the Tube descends no lower than L, then the Water from L to E, join'd to the Weight of the Air which presses upon L, will overpoise the Air at C, and the Water will go out through the Hole C, whilst the Air descending from D to L, and entering Drop by Drop into the Water through the open End L, rises above the Surface of the Water which is below the Neck of the Bottle; but if you incline the Bottle in such Manner that the Point L and the Middle of the Aperture C may be in the same horizontal Line, you will see half a Drop of the Air get below the Point L, but not separate from the rest, unless you raise the End L a little higher.

WHEN you have let some Air into the Bottle, so that the Surface of the Water is at NO, and dilate that Air by heating it with your Hand, you will force out some Drops of Water at C, though the End of the Tube be below this Hole, and the Water will descend as to *p q*, but if you let the Air grow cold again, you will see for some time Bubbles of Air enter in at C; because the Air which had descended as far as P Q, contracting it self within the Space which it took up at first from NO at A H, and there being no Water to fill up the Space NOPQ, the Air must come in from without, through the Hole C.

WATER has no sensible Elasticity, and makes an *Equilibrium* with other Bodies only by its Weight or Impulse: The first *Equilibrium* that is remarkable in Water, with respect to Air, is, that being reduc'd to very small Particles, it becomes lighter than Air, and rises in a Vapour; as was before observed. We can't tell how small such a Particle of Water must be to make an *Equilibrium* with the Air near the Earth, because those Particles, which are a little

lighter or a little heavier than Air, are invisible when they are separate from each other. 'Tis very difficult likewise to find out the Reason of their Rise, for it can't be that they are mix'd with Air, because they would still weigh more than pure Air; 'tis not by Reason of Heat, because we see Vapours arise from very cold Water; 'tis probable then that in the Air there are very fine Pores, void of all heavy Matter, into which these fine Particles of Water may insinuate themselves, and rise therein, and into which the grosser Particles can't enter.

THESE small Particles make an *Equilibrium* with the Air at about a League or two Leagues Distance from the Earth, where they remain a long Time suspended, till many of them being join'd together they become heavier; and when the Air is very much rarefied, they fall to the Earth.

THIS is further illustrated by an Experiment in the Air-Pump; for when you have pump'd out some part of the Air, you see the Recipient grow dull by the Fall of the Vapours, which the Air, by reason of its too great Rarefaction, being no longer able to sustain, they fall in fine little Drops upon the Glass which contains them.

IN Places where there are great Water-Falls, you see Vapours perpetually arise, which are nothing but Particles of Water broken by their Impulse: And when a Soap Bubble comes to break, one Part of the Water, of which it consists, falls, and the rest, being reduc'd to very fine Particles, ascends in a Vapour.

R U L E I.

For the Equilibrium of Water by its Weight.

Water being in one or several Vessels, that communicate with each other, has its upper Parts always upon an equal Level; that is, at equal Distances from the Center of the Earth.

The EXPLANATION. Fig. 5.
Plate 6.

LET AGHC be a recurve Tube, whose Diameter is equal in all its Parts; pour some

some Water into it at the End A, and it will rise to the same Height in the other Leg of the Tube; that is, if D E be an Horizontal Line, and the Water in the Leg A G, rises as far as D, it will rise in the other as far as E, and there continue when you have ceas'd pouring, and the Water is at rest.

FOR, first, if the Legs be of equal Breadth, and equally inclin'd to the Horizon, there being an Equality in every Respect on both Sides, the Water can't remain at the unequal Heights A and F, because the Weight of the Water A G will be greater than that of the Water H F; and consequently in descending it can take to it self a greater Quantity of Motion, than it will give to the other in ascending, since they will have equal Velocities and the same Directions.

THEREFORE by the universal Principle, the Water can't be at rest, unless it be at the same Height in the two Legs. But if you stop the End C with your Finger, before you pour in the Water at A, and fill the Leg A G with Water up to A, the other will be empty, and no Water, or very little at most, will rise into it; because the Air takes up the Place, if the Leg A G be not above two or three Feet in Height; then if you take off your Finger, the Water in the Leg A G will descend, and Part of it will go into the other Leg, and rise as high as E, whilst the other falls as low as N, and afterwards it will rise to D, and fall again as low as M; till at length, after several Vibrations, it will be at rest on both Sides at an equal Height as I F.

WHEN in this Experiment the Water begins to descend from the Leg A to go into the other, it accelerates its Motion till it be at an equal Height in the two Legs, as at I F, where the *Equilibrium* ought to be; and afterwards its Velocity gradually diminishes till it be got to the Points N and E; it descends again after the same Manner, accelerating its Motion from the Height E, till it be past the aforesaid Level I F, and diminishing it till one of the Heights be at D, and the other at M; and these Vibrations will continue

till the Water be at rest at I F, just as a Pendulum accelerates its Motion, till it comes to the Point of Rest, which it diminishes in re-ascending from that Point; and at length, after several Vibrations, stands still.

THE same Thing will happen in a Vessel, as A B C D (*Fig. 6. Plate 6.*) fill'd with Water up to E F; for if by pouring in Water at F, you raise it as high as G, it will not remain in that Situation, after you have left off pouring in other Water: For the Weight of the Water G K H C, being greater than that of the Water K I L H, (L H and H C being suppos'd equal,) it will for the same Reasons overpower it, and raise Water towards I K, and at the same time the upper Surface G K being inclin'd, the Water will move from G towards I; and for the same Reason, the Water E B L I will rise likewise: And at last, after several Vibrations, the upper Surface of the Water will be upon a Level. Hence what happens, when a Stone is thrown into a standing Water, as at N, (*Fig. 7. Tab. 6.*) may be explained; for the Stone raising the Water round it in a Circular Wave, whose Elevation is represented by O and P, it can't remain in that Position; but the Part O will move towards L, and in its Motion will impel and raise the Water next to it as R, which will likewise impel and raise that which follows it, in such manner, that the Water rais'd at O will seem to move as far as L.

THE same Thing will happen to that Part of the Water rais'd at P, and by this Means a circular Wave will arise, which receding from the Point N, will grow larger and larger, till it reach the Banks L and M, if they be not too far distant; and in its Reflection from thence, a new circular Wave will be form'd, which will advance on both Sides towards N, continually enlarging its Circumference, and lessening his Height, till the whole Surface of the Water be got to a Level.

LET us suppose now the two Legs (*Fig. 8. Tab. 6.*) of unequal Diameters, as A B C D, the Water will be at the Height E F, which is the same in both Legs and the

he Column AB; AB will not overpoise the Column CF; for let the Base BG, which is supposed Square, be sixteen times greater than the Base C, and if it be possible, let the Water descend from E to I, and ascend on the other Side to D; that which is suppos'd to descend from E to I, will be equal to the Water contain'd betwixt F and D, and the two little Cylinders FD, EI, will have their Heights reciprocally as their Bases: Then as 16 is to 1, so is the Height FD to EI: Now the Cylinder EB being sixteen times greater than the Cylinder CF, will weigh sixteen times as much: But the Space pass'd through in the same Time by the little Cylinder, will be likewise sixteen times greater than the Space pass'd through by the great Cylinder, and their Directions are the same, both being perpendicular: Then their Velocities must have been reciprocally as their Weights, and they must have had an equal Quantity of Motion, which is impossible; for by the universal Principle, these Cylinders ought to make an *Equilibrium*; and one can't make the other move, because they are dispos'd to take an equal Quantity of Motion, according to the same Direction.

IF you pour Water into the narrow Tube till it be as high as D, it can't remain there in a State of Rest, till the other Leg be fill'd up to A: For let the Height FD be an Inch, and its Base an Inch, and the Water BE, 160 Cubic Inches, and FC 10 Inches, then the whole Column of Water CD will be 11 Cubic Inches. If then the whole Column CD falls an Inch, the Water EB will rise $\frac{1}{16}$ of an Inch; viz. the Height EL, and the Space EL will be the Measure of the Velocity of the Water BE, as DF is that of the Water CD: Now 160 multiply'd by $\frac{1}{16}$, gives 10 for the Quantity of Motion, and 11 multiply'd by 1 gives 11; then the Quantity of Motion of the Water DC will be greater than that of the Water BE, or which is the same Thing, the Velocity of the Water in the small Tube will be greater in Proportion to the Velocity of the Water in the great Tube, than

the Weight of this latter is to the Weight of the former; and by the universal Principle the Water in the small Tube must descend. The same Consequences may be drawn with respect to other unequal Heights, till the two Surfaces of the Water in each Leg be upon a Level, nor will the Water be at rest, till it be at the same Height in both.

THE Water AG may be still further considered, as divided, according to its Length, into sixteen little square Columns, each of which may be supposed equal to the small square Column CD; and because none of these small Columns can rise higher, or fall lower than the others, the same may be concluded of the little Column CD, though it be not contiguous to them.

HENCE it follows, that if you put a floating Body upon the Water in the Leg AB, and the Weight of the Body be equal to that of the Water contain'd in the Height AE, when that Water is pour'd off, the Water in the little Leg will still remain at the Height CD, and there will be an *Equilibrium* betwixt the Column CD, and the Water BE, joined to the Weight of the Floating Body, for the Reasons above-mentioned.

WHEN the narrow Leg is very small, as about half or one third of a Line in Diameter, the Water will rise an Inch or two higher in that, than in the other Leg; which likewise happens when you dip a Glass Tube, whose Diameter is less than one Quarter of a Line, into Water, for it will rise therein to the same Height of an Inch or two above the other Parts of the Water's Surface, and the whole Quantity of Water that rises above the Level, in Tubes that are very small, or in such as are only moderately so, as about a Line, or half a Line in Diameter, is sensibly equal to a great Drop of Water, that being fix'd to some Body hangs at it without falling.

THE same Effect may be seen in the Experiment of the Bottle before mention'd (*Fig. 4. Tab. 6.*); for if the Tube be very small, as about half a Line in Diameter, the Wa-

ter will fall in it no lower than L, about an Inch above E, and then this particular Cause of Adhesion resists the Effort of the Air, which is above the Water in the Tube; and the narrower the Tube is, the higher the Point L will be.

SOME attribute the Cause of this Effect to the Weight of the Air, which acts with its full Force upon the Water in the large Tube, and can't act so well upon that in the small one; but this can't be the Reason: For if you dip such a Tube in *Mercury*, it will not rise so high in it as the Level of the rest of the *Mercury*; and yet in this Case the Weight of the Air ought to have the same Effect upon the *Mercury* that it has upon the Water: Whereas, if one of these narrow Tubes, that is not above half an Inch high, be dipp'd in Water, the Water will rise in it to the Top, altho' the Air has then no Difficulty to insinuate it self. And for a further Proof, if the Sides of the Tube be thick, or if it has been some time without Wetting, it contracts a certain greasy Substance, which the Water can't fix upon; and then the Water will not rise above the Level, though the suppos'd Defect of the Weight of the Air continues the same without Alteration.

THIS Effect then is to be explain'd by the same Reasons, that make Water in a Vessel of Wood rise above a Line and an half towards the Sides with a little Concavity, which causes Two Drops of Water to join together, when they touch each other, of which Reasons I have spoken at large in the first Discourse.

A surprizing Effect of the *Equilibrium* of Water may be seen in the following Experiment: Take a Vessel or Butt of Water, about two or three Foot broad, as A B C D, (Fig. 9. Tab. 6.) make an Hole at the Top, as at E, and fix a Tube therein of an Inch Bore, so closely join'd with Hurds and Pitch, or other glutinous Matter, that no Air can get into it, and let this narrow Tube, viz. E F be 12 or 15 Inches high; fill the Vessel with Water by some Holes made in the Top, and afterwards stopp'd up, and put thereon Se-

ven or Eight Hundred Pound Weight which will sink that Top to a Concavity, as A M D; if you put a white Mark on the outside of the Tube, as at the Point H, and at the Side a little higher a Rule or Index, as I L plac'd in a neighbouring Wall; and fix'd in such Manner, that it may remain immoveable; as you pour Water by little and little into the narrow Tube E F, you will see, when it comes to be full, that the Top A M D, together with the 800 Pound Weight that it bears, will be rais'd not only to its first Situation A E D, but that it will take even a Convex Figure, and be rais'd in the Middle as much above the Point E, as the Point M was below it before; which you will see by observing the white Mark H rise by Degrees above the Ruler I L, with which you may measure the Difference. And if the Tube be longer, the Elevation of the Weight will still be greater: Whence you may conclude, that the small Quantity of Water in the Tube has as much Force to raise this great Weight, and push up the Top of the Vessel to a Convexity, as if the Tube were of the same Bore or Breadth as the Vessel. This Effect is prov'd by the same Reasons before-mentioned, concerning the Water in the small Tube C D, which will raise the Water in the Tube B A (Fig. 8.) when 'tis no higher than E, tho' it should weigh a thousand times as much: For the Velocity which the Water in the small Tube F E (Fig. 9. Tab. 6.) will take in its Descent, will be to the Top of the Vessel in ascending, as the Surface of this Top is to the Surface of the Water in the Tube; that is to say, if the Tube be an Inch in Diameter, and this Top of the Vessel 30 Inches, the Surface of the Top will be 900 times greater than the upper Surface of the Water in the Tube: Then if the Water in the Tube descends an Inch, that which touches the Top of the Vessel, will rise but $\frac{1}{900}$ Part of an Inch. And consequently, if the Water in the Tube weighs a Pound, it will make an *Equilibrium* with 900 Pounds, then it will raise the 800 Pounds that are on the Top of the Vessel

Vessel, with the little Quantity of Water that is above A E D; but for the greater Exactness of the Calculation, and of the Manner of Reasoning, you must suppose that the whole Top of the Vessel rises all at once.

WHEN one of the Legs of a Syphon is inclin'd, and the other perpendicular, both being pretty near of the same Diameter, Water in that Syphon will likewise be upon a Level; (*Vid. Fig. 10. Tab. 6.*) for let the Syphon A B C be plac'd in such Manner, that the Leg A B may be perpendicular, and C B inclin'd to the Horizon, it is manifest that the Weight of the Water in D B will be to the Weight of the Water in E B, as the Bulk D B is to the Bulk E B; but if E D be an Horizontal Line, the Sum of the Force, which the Water E B has to descend, will be to that which it wou'd have if it fell perpendicularly, as the Length E B is to the Length D B: Therefore it will make an *Equilibrium* with the Water D B, whose Direction is perpendicular, according to the universal Principle; for the Spaces pass'd through in the same Time by both Quantities of Water in each of these Tubes, according to their natural Direction towards the Center of the Earth, will be in a reciprocal Proportion of their Weights; that is, as the Weight of E B is to that of D B, and consequently the Water E B will not overpower the Water B D; the greater Friction in the long Tube may cause some Difference, and a little retard the Motion of the Water along the inclin'd Plane E B; but altho' either of these Tubes should be larger than the other, that wou'd not hinder the *Equilibrium* for the Reasons above-mention'd.

WHEN a Syphon has one of its Legs much larger than the other, as in the 21st Figure, stop the Mouth of the little Leg with your Finger, and afterwards fill the great one with Water, then take off your Finger all at once, and you will find that the first Motion of the whole Column of Water A B is retarded, by Reason of the Difficulty which it meets with

in its Passage at G; but the Motion through F C is much faster in its Beginning, than when the two Legs are of equal Bore; whence it happens, that if you pour a little Water into the Leg F C, till the Tube of Conjunction B C be full, and after you have stopp'd the Mouth F with your Thumb, you fill A B, the other Part of the Syphon, up to the Horizontal Line E D, and then take off your Thumb all at once, the Water will rise higher than D, even up to F, because the Water in the great Leg, though it descends slowly, yet it makes that in the little one rise very fast, and all the Water being in Motion, in order to come to an *Equilibrium*, it still moves (after it has got thither) by its acquired Velocity, as appear'd in the uniform Syphon; which causes the Water in the great Leg to descend still, and make the other rise Three or Four Inches above D from whence it descends again, and after some Vibrations stands at last at the same Height, in both Legs below E F; and though the Tube A B should be full before you take off your Thumb, the Water would still spout up Three or Four Inches higher than F, provided the Leg A B be much larger than C D; for then the falling and rising in this large Leg will be very small, and almost insensible. These are the Experiments that have been made concerning it.

I took a Vessel made of Tin, as A B C D, (*Fig. 12. Tab. 6.*) of Four Inches Diameter, which had a Tube E F, to which I join'd a bended Glass Tube, as F G H; I fill'd the Vessel and the Tube E F, after I had stopp'd the Mouth at H with my Thumb, to hinder the Air from getting out; and when I had taken off my Thumb, the Water spouted up to I, Three Inches higher than the Surface of the Water D A; but when the Glass Tube reach'd Five or Six Inches higher than A D, the Water rose in it Four Inches higher than H, from whence it fell again, and at length came to an *Equilibrium*. The same Experiment was made in a Tube L E F, whose Diameter was

B.

equal.

equal throughout, GH being still narrower than LEF , and the Water spouted up above the Point H , just as it did when the Vessel AD was above EF : Now in these Cases the Water begins to rise pretty fast at G , and afterwards rises a little faster when the Water LE has acquired some Motion. But this Velocity in the Passage from G to H begins to diminish, when the Water in each Tube or Leg is come to an *Equilibrium*, that is, to the Height at which it ought to stand in both the Tubes, as to the Horizontal Line KM . But if you put different Liquors in the two Tubes, the lightest will be higher than the other, in a reciprocal Proportion of their Weights. The Rules of which are as follow.

A Rule for the Equilibrium of different Liquors by their Weight.

THERE are two Sorts of Gravity in Bodies here to be considered; one proceeding from the Mass or Bulk of the Body, as a Cubic Foot of Wood weighs more than a Cubic Inch of the same Kind of Wood; the other proceeding from the Density of Bodies, or from some other Reason by which one Body weighs more than another of equal Bulk, as a Cubic Inch of Gold weighs more than a Cubic Inch of Iron; this latter we call *Specific Gravity*; thus the Specific Gravity of Water is greater than that of Oil; the Gravity of the Air, in which the Body is weigh'd, is not here consider'd, though in Strictness it ought to be.

LET there be an *Equilibrium* of Water at the Height DE , in the Syphon ABC (*Fig. 13. Tab. 6.*); pour some Oil gently into the Tube CD , to the Height C , then

you will see the Water descend below E , and rise about D in the other Tube; let EF be the Measure of the Descent, and DG of the Elevation, and draw the Horizontal Line FH ; then the Oil FC will be to the Water HG reciprocally, as the Specific Gravity of the Water is to that of the Oil; for the Water FB will make an *Equilibrium* with the Water BH , then the Oil FC will make an *Equilibrium* with the Water HG ; now that the whole should remain in this Situation, 'tis necessary that the Parts H and F should be equally press'd, from the above mention'd Principle: Then the Quantity of Oil FC will weigh as much upon F , as the Water HG upon H . The same Effect will appear in Mercury and Water; for if you put Mercury into the Syphon ABC to the Height DE , and then pour in Water gently at C , inclining the Syphon a little at first, to hinder the Water's mixing with the Mercury, and let the Water rise up to C , and the Mercury to I , the Water will then fall to the Horizontal Line KL ; and the Water KC , together with the Mercury KB , will make an *Equilibrium* with the Mercury BI ; and as the Specific Gravity of Mercury is to that of Water, so reciprocally will the Height KC be to the Height LI , and by this Means it will be easy to determine the Specific Gravity of Liquors with Respect to each other; for if Mercury weighs fourteen times more than Water, KC will be fourteen times longer than LI .

AND thus I have trac'd the *Equilibrium*, or Weight of Air in Respect to Water: As to the Balance of Wood, Wax, and other Metals, with which *Mariotte* goes on, it will be needless to insert it in this Place.



The End of the Notes of the second Book.